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TREASURY DEPARTMENT

UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 128

DECEMBER, 1922

TRANSACTIONS OF THE TWENTIETH ANNUAL CONFERENCE OF STATE AND TERRITORIAL HEALTH OFFICERS WITH THE UNITED STATES PUBLIC HEALTH SERVICE

HELD AT WASHINGTON, D. C.
MAY 17 AND 18
1922

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1922

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Dr. W. F. Cogswell.
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TWENTIETH ANNUAL CONFERENCE OF STATE AND TERRITORIAL HEALTH AUTHORITIES WITH THE UNITED STATES PUBLIC HEALTH SERVICE.

TRANSACTIONS.

MORNING SESSION, WEDNESDAY, MAY 17, 1922.

The Twentieth Annual Conference of State and Territorial Health Authorities with the United States Public Health Service was called to order at 10 o'clock a. m., May 17, 1922, at the American Red Cross Building, Washington, D. C., Surg. Gen. Hugh S. Cumming presiding.

The following persons were present during the conference:

REPRESENTATIVES OF THE STATE HEALTH DEPARTMENTS.

Alabama: Dr. S. W. Welch.
Arkansas: Dr. C. W. Garrison and Mr. M. Z. Bair.
California: Dr. S. W. Hazelhurst.
Connecticut: Dr. John T. Black and Mr. J. F. Jackson.
District of Columbia: Dr. W. C. Fowler.
Hawaii: Dr. F. E. Trotter and Mr. S. W. Tay.
Illinois: Dr. J. D. Rawlings and Mr. H. F. Ferguson.
Indiana: Dr. W. F. King.
Iowa: Dr. R. P. Fagen and Mr. H. V. Pedersen.
Kansas: Dr. S. J. Crumbine.
Kentucky: Dr. A. T. McCormack.
Louisiana: Dr. Oscar Dowling.
Maine: Dr. C. F. Kendell.
Maryland: Dr. John S. Fulton, Mr. C. H. Jones, and Mr. R. B. Morse.
Minnesota: Dr. A. J. Chesley and Mr. H. A. Whittaker.
Mississippi: Dr. H. Hays.
Montana: Dr. W. F. Cogswell.
Nebraska: Dr. I. H. Dillon.
New Jersey: Dr. R. B. FitzRandolph and Dr. A. J. Casselman.
New York: Dr. J. S. Lawrence, Dr. M. Nicoll, jr., and Mr. Theodore Horton.

North Carolina: Dr. W. S. Rankin, Dr. H. E. Miller, and Dr. J. S. Mitchiner.

Ohio: Dr. H. H. Snively, Dr. James E. Bauman, and Mr. W. H. Dittoe.

Oregon: Dr. F. B. Stricker.

Pennsylvania: Mr. C. A. Emerson.

Rhode Island: Dr. B. U. Richards and Mr. Stephen De M. Gage.

South Carolina: Dr. James A. Hayne and Dr. E. L. Filby.

Tennessee: Dr. W. J. Miller, Dr. R. Q. Lillard, and Mr. C. N. Harrub.

Texas: Dr. W. H. Beazly and Mr. V. M. Ehlers.

Utah: Dr. T. B. Beatty.

Vermont: Dr. C. F. Dalton.

Virginia: Dr. E. G. Williams and Dr. R. K. Flannigan.

Washington: Dr. Paul A. Turner and Mr. C. E. Dorisy.

West Virginia: Dr. W. T. Henshaw, Mr. E. S. Tisdale, and Mr. J. T. Dillon.

Wisconsin: Dr. L. W. Hutchcroft.

REPRESENTATIVES OF THE UNITED STATES PUBLIC HEALTH SERVICE.

Surg. Gen. Hugh S. Cumming.

Asst. Surgs. Gen. C. C. Pierce, C. H. Lavinder, J. W. Kerr, J. W. Schereschewsky, A. J. McLaughlin, R. H. Creel, and B. S. Warren.

Directing Zoologist (R.) C. W. Stiles.

Senior Surg. Benjamin W. Brown.

Surgs. John McMullen, L. L. Lumsden, G. W. McCoy, L. D. Fricks, T. Clark, J. Goldberger, L. R. Thompson, J. P. Leake, A. M. Stimson, W. F. Draper, and W. H. Frost.

Passed Asst. Surg. M. V. Ziegler.

Associate Sanitary Engineers Sol Pincus, L. M. Fisher, and H. W. Streeter.

Assistant Sanitary Engineer I. W. Mendelsohn.

GUESTS.

Miss Grace Abbott.
Miss S. C. Barks.
Col. Edward Clifford.
Dr. Harold S. Diehl.
Mrs. Sarah C. Fernandis.
Dr. John A. Ferrell.
Dr. A. W. Freeman.
Dr. L. R. Goldsmith.
Miss Matilda Lindsay.
Miss Agnes Meagher.
Dr. Lena L. Meanes.
Mr. O. W. Meinzer.
Dr. William H. Park.
Dr. Valeria Parker.
Mrs. E. C. Slagle.
Dr. William F. Snow.
Dr. Elizabeth B. Thelberg.
Mrs. Elizabeth Tilton.
Dr. Rachel Yarros.

OPENING REMARKS BY THE SURGEON GENERAL.

Doctor CUMMING. Will the conference please come to order, as we have a rather full program which we desire to complete.

I take pleasure in opening this, the Twentieth Annual Conference of State and Territorial Health Officers with the United States Public Health Service, and in expressing my thanks to you as health authorities of your States and representatives of your State governments for being present at the conference, because I know how many conferences you have attended in the past few months and how many are ahead of us.

I think it is rather encouraging that in spite of the reactionary feeling with regard to appropriations which followed the war, appropriations for the Federal service and, as far as I gather from State officials, State appropriations have not been reduced. I think that is a matter for congratulation.

The service fared pretty well during the present year so far as appropriations are concerned. Congress and the legislatures have been fairly liberal, under the circumstances, showing that the importance of public health is beginning to be appreciated.

So far as the Federal service is concerned, despite the feeling that the ex-service man problem interfered with us, we really have been doing more cooperative work than ever before with the State and Federal departments.

This particular phase of the Public Health Service work is developing very rapidly, and the sympathetic attitude of the President, the Postmaster General, Dr. Hubert Work, and other members of the Cabinet will, I am sure, result in good to the States and to the Federal Government.

With the acquisition of the New York quarantine station the Federal control of national quarantines is now complete.

Since our last meeting there have been fundamental decisions of the Supreme Court which pretty clearly outlined the police powers of the Federal Government with relation to the States. If you have not read the decisions relative to the child-labor act, I advise you to do so, because there is a good deal of misapprehension along that line.

I feel that with the outline of the legal responsibility before us there is a greater need for close and sympathetic cooperation in the problems which we mutually have to attack, and I am thankful to say that, so far as I am aware, there has never been better understanding and coordination of effort than there has been between ourselves during the past year or so.

I am not going to take the time to go over the events of the last 12 months. Some of the things are of sufficient importance to mention—for instance, the growing realization of the fact that the development of adequate local health service is the principal means for the protection of the health of the citizen; and the necessity for better health protection during the age of infancy, growth, and development.

In addition to the attention which has been called to these fundamental principles, progress has been made during the year on the problem of eliminating malaria from the United States. When this shall have been successfully accomplished we may expect an increase of at least 30 per cent in the health and prosperity of those sections of our country where this disease is now prevalent.

Another significant thing is the recent conference between the Public Health Service and educational authorities respecting the problem of supplying trained workers in the field of public health. This has more than a surface significance, for it surely indicates that the demand for trained health workers is beginning to outrun the supply, showing that advances in the extension of public health work are pending and that the future is bright with possibilities.

I will not take time to speak longer. The program is full and offers many important subjects for discussion.

I bid you a most hearty welcome and declare the Twentieth Annual Conference of the State and Territorial Health Officers with the United States Public Health Service now open. Since this conference is the legal machinery through which the State health authorities have their advisory voice in Federal health matters, let me urge upon you the duty you have of fully expressing yourselves upon these matters, not only with respect to the program but about any other line affecting the relations of the Federal Health Service with the States.

(The secretary called the roll.)

Doctor CUMMING. In view of the large number of people present here this morning, it may be well for me to state that this is an official gathering, representing the States, and when the question of voting comes up the only people entitled to vote will be the official representatives of the State governments.

The first thing in order is the report of the standing committee, morbidity returns, by Dr. Eugene R. Kelley. Doctor Kelley told me he had to return to Massachusetts, and I do not know whether he left anybody to report for him.

(No response.)

Sanitation of public conveyances, by Dr. Oscar Dowling.

SANITATION OF PUBLIC CONVEYANCES.

Doctor DOWLING. There is really nothing new to offer, but I have submitted for the committee a short report.

Doctor Dowling thereupon read the following report of the committee:

REPORT OF COMMITTEE ON SANITATION OF PUBLIC CONVEYANCES.

Your Committee on Sanitation of Public Conveyances begs to report that the recommendations made in 1921 are sufficiently adequate if they could be enforced.

We make two additional suggestions—more as suggestions than recommendations—namely, that spittoons with running water, similar to the dental arrangement of lavatories, be placed in smoking rooms and parlor cars; and that, if at all practicable, ceiling fans additional to those at the end of the cars be placed in all coaches where electric fans are now used.

Doctor CUMMING. Gentlemen, you have heard the report. Is there any discussion? What will you do with this report?

Doctor HAYNE. Will the secretary read it? I do not think the members grasped the significance of it.

Doctor SCHERESCHEWSKY. The secretary will read the report again.

(The secretary thereupon read the report.)

Doctor DOWLING. For those recommendations you are referred to the report of the transactions of the last conference. We make two additional suggestions—more as suggestions than recommendations. They are as follows:

(Doctor Dowling read the recommendations or suggestions above referred to.)

Doctor FREEMAN. I do not know whether I have the privilege of the floor at this gathering or not, but if I understand the action of the conference taken on the report of the committee on railroad sanitary regulations it provided that no action should be taken for a five-year term. We have just completed a very long drawn-out discussion, getting everybody to agree to the sanitary regulations. If we argue for two days on that set of records, we will be where we were and work done on that will be lost, and I would suggest that these suggestions be referred to a standing committee or a special committee on amendments. If we do anything now, it will throw the whole thing into chaos.

(It was moved and seconded that the matter be referred to a committee.)

Doctor WELCH. These things suggested for amendment are referred to the executive committee of State and Provincial health officers, and I would be inclined to accept the report. The general code has been published, distributed, and adopted by the State of Alabama, and we do not want to be bothered with adopting more amendments. We have adopted some amendments, and they have not gotten cold from their adoption. Since these have been printed, we are opposed to any amendment of the code at the present time

Doctor CUMMING. The Chair will entertain a motion to lay it on the table.

Doctor WELCH. I move that it be laid on the table.

A MEMBER. I second it.

Doctor CUMMING. All in favor of laying the motion on the table for the present time will say "aye."

(Motion carried.)

A MEMBER. There will be no need for continuing the committee, will there? If you are only going to take it up within five years time there is no need of the committee.

Doctor DOWLING. I move that the committee be discharged with the thanks of the conference.

Doctor CUMMING. Is there any discussion on this?

Doctor DOWLING. I want to say this: I will read the report:

(Doctor Dowling thereupon read the report.)

This was merely a suggestion, not a recommendation. As I said, if you are not going to consider anything except in five years, it would be carrying dead matter to carry a committee.

Doctor CUMMING. I was not attempting to influence the decision. I suggested one method of disposing of it, temporarily laying it on the table. I have not appointed a committee. I can take it up at any time. The Chair is a little confused about the parliamentary condition of the motion, and particularly with reference to the committee to which Doctor Freeman alluded. What committee is that?

Doctor FREEMAN. The committee on standard railway sanitary code, and the provincial health officers, which has just completed the work of getting everybody into agreement on the problem, and which I think was discharged at the meeting just held.

A MEMBER. That is correct, and the report was approved by the service and distributed.

Doctor CUMMING. The Chair does not claim to be a parliamentary expert at all, unfortunately, and we want to dispose of this thing after a full discussion. I am open to suggestion as to what to do about it.

Doctor DILLON. A standard railway code has been promulgated and adopted by a number of States, and it will be adopted by other States. It seems to me the height of folly to change the code just as soon as you have adopted it, by making minor changes in it, and I believe that a period once every five years for a revision of that code is amply often to revise it or change it to meet the growing conditions and growing needs, and I see no reason why suggestions of this kind should be adopted or rejected one way or the other If they are adopted now and held in abeyance for four or five year they are forgotten, and it occurs to me, if a committee could be appointed in 1924 to begin considering the things that will come up for revision at the end of the five-year period, that that would be the time to begin making reports for the change of rules on sanitation of railway coaches and conveyances.

Doctor DOWLING. May I say for the committee that the report is as follows:

(Doctor Dowling thereupon read the report.)

I think you will do remarkably well if you enforce them. I am willing to withdraw the suggestion, with the hope that it will be enforced, and I would like to have somebody report from one State where they have been enforced.

Doctor CUMMING. This is the original report.

Doctor DOWLING. We will withdraw the suggestion. It was made as a suggestion, and not to be adopted as a regulation. It is made as a suggestion, food for thought. You will all agree that expedients invite spitting, and of all the people that should not spit are the health officers of the various States of the United States.

A MEMBER. I move that the amended report be received.

Doctor CUMMING. Is there any discussion?

A MEMBER. I second it.

Doctor CUMMING. All in favor of the adoption of the amended report will so signify by saying "aye."

(The report, amended by leaving out the second paragraph, was adopted.)

Doctor CUMMING. The report on interstate quarantine regulations, Dr. John S. Fulton.

Doctor FULTON. No suggestions of any kind modifying the interstate quarantine regulations have come to my knowledge, so there is, therefore, no report.

Doctor CUMMING. Report on rural health work, Dr. W. S. Rankin.

Doctor RANKIN. I would like to suggest that that be postponed until the afternoon session.

Doctor CUMMING. Is that agreeable to the chairman of the committee?

Arrangement has been made with Doctor Williams for the conference, after the lunch-time period, to meet in the Arlington County courthouse, to give Doctor Williams an opportunity to show some sanitary work. He consulted with most of you gentlemen, and it is agreeable. Conveyances will be down here to carry you over to meet in Arlington County courthouse.

The report on trachoma, Dr. John McMullen.

Doctor PIERCE. If Doctor Rankin will give his report this afternoon, I would ask that Miss Thelberg be given the floor at this time.

She wants 10 minutes to show how women's organizations can cooperate.

Doctor CUMMING. Is there any objection?

(No objection.)

COOPERATION OF WOMEN'S ORGANIZATIONS.

Doctor THELBERG. Officers of the State and Territorial health authorities, to whose kindness I owe this opportunity to present just the merest glimpse of what we women want, what we are interested in, and how most of all we want to help you in your State and Territorial work, it requires some courage to face so large a body of distinguished men and women, but courage is a relative thing, you know.

You have all heard of the man who slept with lions. This man was a menagerie keeper, and before the passage of the eighteenth amendment he came home and did not like to go upstairs. Then he bethought himself of the lion's cage, and after hesitating awhile he went across the street into the stables where the animals were kept, and he rolled back the door of the lion's cage and crept in and spent the rest of the night. In the morning his wife awakened and found that he was not by her side, and she was very angry. She could not find him anywhere, until it occurred to her that she must feed the animals, and she hurried across the street and looked in the door of the lion's cage and saw her husband lying alongside of the lion, and she said, "Come out of there, you coward."

It is not a matter of cowardice.

We thank you for asking us all here, and I thank you personally for giving me the chance to tell you that story and say some other things. You will remember the story.

I want to tell you about our meeting yesterday. We had a meeting of the advisory council, and it was a most instructive and interesting day. We had the very great pleasure of listening to Doctor Hamilton, and we were so proud. I wish that you could have heard Doctor Hamilton speak. The doctor is perhaps the greatest authority upon industrial hygiene, not only in America but in the world. We are indebted to her and others who instructed us yesterday.

We passed some resolutions in relation to industrial hygiene. We feel, as women workers, that we are too profoundly ignorant about the basis of industrial hygiene; and I am sure that the resolution we passed in our hearts as well as those we passed on paper will be handed up higher, and we will be stimulated by that meeting yesterday, become more intelligent in relation to the basis of industrial hygiene, and we will endeavor to extend that intelligence into the organizations which we represent, and, further, into the educational institutions which some of us represent and in which all of us are profoundly interested.

Is there any reason why courses in general sanitation, with particular attention paid to industrial hygiene, should not be put into our colleges, both for men and for women? Is it not possible that our Government in general or the two Houses of Congress might be made more intelligent if during their college days or later high-school days the Members should have had the benefit of such a course? Would not health conditions improve by the introduction of such courses in our schools? We teach a great many things which are infinitely less interesting and less important to life in general than such courses would be.

About yesterday: In relation to our present fears, I want to tell you one or two things. You do not know how interesting these women in the back of the room with you are. For instance, we have with us Mrs. Fernandis, who represents 250,000 colored women of America, all organized into well, finely acting, intelligent club people. That is a tremendous force, a force to be reckoned with in the work which we want to do among people of her color in this country of ours.

I sat, during the international council in Norway, during that whole 10 days by the side of the then president of the colored women's organization, a graduate of Oberlin University. She is of a family of 10 children, and all of them are college graduates; Mrs. Talbot was most honored in Norway, and was a great and valuable addition to the intelligence of the American women's council delegation.

We have here also Mrs. Tilton, of Massachusetts, who represents 300,000 women, the Parent-Teachers and Mothers' Congress Association. If you could secure the votes of those women in sanitary measures in all the States of the Union, you would carry many things which you find difficult now.

Also we have with us Mrs. (also Doctor) Goldsmith, of Pittsburgh, who represents the Jewish Women's Council of America, not thousands, but a million women of extraordinary intelligence, of extraordinary interest in matters pertaining to the welfare of the country, which is our country.

We also have a representative of the Medical Women's National Association here, not thousands, hundreds, but a very great number, picked women, women of great power in their communities, and women whose power is being extended by the closest cooperation with the women of their vicinities or the communities in which they dwell.

We have also a representative of the Women's Foundation of Health, which represents 14 national societies. That runs up into the millions. They have a great ideal, those women have.

You remember when Jean Paul Richter lay dying he said, "Give me a great thought that I may quicken myself with it." These women have gotten hold of a great thought, the thought of health, as a positive factor in human life. We have that thought and are looking forward, but they are advancing that thought, trying to advance health as a new presentation of a thought, and they are also becoming more and more tremendously powerful, and their power is added to by the fact that they represent the hundreds of thousands of women of the Y. W. C. A., one of the strongest factors for good in our land.

We have representatives of the League of Catholic Women, which runs again into millions.

We have a representative of the League of Women Voters, hundreds of thousands, represented by women of great ability.

We have the General Federation of Women's Clubs. With that association, to which, I suppose, most of your wives belong, you are more familiar. Four million women are incorporated into the women's clubs in this country. Think of the power for good, and the possible power for evil. They may be led astray here and there by faddists and by quackery, but it is up to us and to you to educate them so that they will be sane on all these subjects.

These four million organized women are much more in the habit of addressing audiences than I am. It will never be said of them as it was said of a Senator some time ago. He had been talking for two hours, and somebody said, "The Senator has been talking for two hours." "What about?" "He did not say." When they talk they know what to say.

We have a representative of the National Council of Women of America representing 11,000,000 women. That is a good many women, isn't it? It is frightful to think of. Matthew Arnold said a long time ago that if women ever got together for a good purpose they could make the world over. You have given us the vote. Some of us are ready and some of us are not ready, but we want to get ready. It is a source of great pride to us representatives of these hundreds of thousands of women that you ask us to come here to-day. Did you ever stop to think that we are all members or citizens of some State or Territory? We care for our State profoundly. We look upon you and upon your functions with (I do not think I go too far when I say this) reverence. It is one of the greatest things and greatest ambitions that any human being can look forward to, to be in charge of health conditions in a State or Territory. None of us women has done that yet, and perhaps none of us ever will, but, gentlemen, it is my opinion that the sooner we get into straight political lines of work, the better; not definitely for office, and yet there are women who adorn the office which they fill.

Is there a more useful woman than Dr. Josephine Baker, of New York City, who has so reduced the death rate in her city that it is lower than the rural death rate anywhere in our country?

We women have walked along the primrose paths of philanthropy a great many years. It taught us a great deal, but I firmly believe that if we are going to do the best job we can, we shall get in the straight path of politics; yes, even of political preferment—I am not ashamed of an ambition that way, though I have not any personally—but I have a great respect for the young woman who has, and I believe that we have exerted that influence of ours in unseen ways to little avail. There has been more talk than anything else. Why should not women have an ambition to be health officers in their town and village? Some of them have been fine. Why should not they get on the local health board? Why should they not effect good toward righteousness and toward that intangible thing which we call health of mind, body, and spirit? We thank you for the opportunity of coming here and learning. We are perfectly conscious that we do not know the game yet. We want to learn. We learned yesterday and we are learning to-day.

I never attended a meeting in my life which so increased my intelligence as the meeting I attended in Boston with many of you gentlemen last year.

I am grateful to the Surgeon General for the invitation to that meeting, and I am sure that we are all grateful for the opportunity to be here with you to-day.

I thank you.

Doctor CUMMING. I am sure I express the views of all of you when I thank the preceding speaker for the interest of the women in our work.

Doctor SCHERESCHEWSKY. I will announce the members of the resolutions committee. They are Doctors Dalton, Fulton, Crumbine, Hayne, Dowling, Rankin, and Stricker.

Doctor CUMMING. We will now hear from Doctor McMullen.

TRACHOMA.

Doctor MCMULLEN. Mr. Chairman and gentlemen of the conference, the trachoma work has been conducted in much the same manner as in previous years. The outstanding features this year are the clinics and the establishment of an additional hospital in Arkansas, with the thorough cooperation of the State board of health, Doctor Garrison, and the local authorities.

The most prominent piece of trachoma work during the year was a clinic conducted in south Georgia. It was a great surprise to me, and I presume it will be to a number of you, to know that in one of the counties of south Georgia we found active communicable trachoma existing in about the same way that we have heard so much about and for so long a time in eastern Kentucky and Tennessee. The investigation was made in the fall, at the request of the State health officer. I personally made the investigation and found entire families with trachoma. Not a few of these had lost their sight entirely, and even more had lost the sight of one eye. It was very interesting to trace the origin of this disease. It dated back about four generations, where it was lost. I noticed that the State health officer of Florida did not respond to his name a few minutes ago, so I will not say much about that. The lady who was the mother of some of the trachoma patients, and a patient herself, stated that her mother had spent a portion of her childhood in Florida and had suffered with sore eyes at that time. I wish the Florida health officer were here.

The clinic in south Georgia was conducted by the service, which furnished medical officers and two nurses; the county furnished the building, which was a very modern hospital, built by some doctor two years ago in the hope of conducting a successful hospital. This small hospital went the way of the usual small institution and did not pan out economically, with the result that it was closed. The county was, therefore, able to obtain the vacant building. The clinic lasted four and a half months—November 14, 1921, to April 1, 1922. The attendance was more than 3,000—the trachoma cases amounted to nearly 300—and the operations were 381. I might add that all of the operations were not on trachoma. At the request of the State health officer, the local doctors, the commissioners who paid the bills, and the eye specialists we undertook to treat indigent cases. The operations included anything from cataract to tonsils, adenoids, etc. It might be said that these cases were done as an accommodation to the county commissioners.

The general trachoma work included 27 clinics in rural communities. At these clinics more than 5,000 people were examined. Six hundred and eighty-six cases of trachoma were found. Four hundred and ninety-eight operations were performed, 158 being done under general anesthetic.

These clinics were held in various States, the majority of them in Kentucky. Some were in Ohio, Texas, Mississippi, Tennessee, and North Carolina.

The State of Kentucky has now a bureau of trachoma which is cooperating with the service trachoma work. Other States are becoming more interested in the trachoma problem.

These, then, are the outstanding features of the work for 12 months. The sixth hospital has been in operation only a few weeks, having been opened in Arkansas about the middle of April. The total attendance at the other five hospitals during the year was 6,532. There were 561 cases of trachoma among those applying for treatment and 687 operations performed. Eight hundred and fifteen cases were admitted to the hospitals for treatment. The cost of operating the hospitals is very low, the average cost of feeding the patients being about 50 cents per day each, though a properly balanced diet for the patients is part of our treatment. As I have previously stated, these hospitals are conducted purely in the interest of public health and not primarily for the treatment of disease, and the patients are taught hygienic living, the fruit of these teachings often being the higher mental, moral, and physical standards that are attained.

Doctor CUMMING. At the request of the Veterans' Bureau we are devoting a hospital now to the treatment of trachoma among ex-service men. This is a very recent thing, since the President's order.

The next report is a special report by Doctor Stiles—a progress report of the board appointed by the Surgeon General to study the problem of sanitary disposal of human excreta in unsewered communities.

ANNUAL (1921-22) REPORT OF THE BOARD[6] ON EXCRETA DISPOSAL, PRESENTED TO THE STATE HEALTH OFFICERS' CONFERENCE, MAY 17, 1922.

Doctor Stiles submitted the following report:

From some points of view the Government fiscal year 1921-22 has been the most exceptional of the past 31 years.

Changes in Government methods as respects certain routine procedures in business matters, changes in methods of accounting, insufficient number of permanent personnel, uncertainty as to the future on the part both of permanent and temporary, statutory and lump sum, commissioned and civil service personnel, increase in reports required, but without corresponding increase in personnel, orders to save every dollar possible and in addition to save 10 per cent of allotments, numerous circular letters of instructions, or inquiry of all types, etc., have all combined to render this transitional year one of unusual difficulty in progressive work.

This is neither a complaint nor an apology, but simply a statement of fact.

One might wonder how this transition could seriously affect the work of a small unit like that of the board on excreta disposal. Permit me to mention two points in particular.

Never during 31 years of Government service have I known any more ardent desire and conscientious effort on the part of a major bureau to expedite requisitions than has obtained this past year in the Surgeon General's Office, and never have I experienced so many delays in obtaining supplies. As soon as the new order of affairs shall have passed from the transitional stage to a settled routine, these delays (which are at present unavoidable) will doubtless decrease both as to number and as to time. But, speaking from no small experience in Government life, I can not escape the conclusion that in the days of 1891 to 1900 the economy in a field unit was greater than it is to-day, and that this fact was due largely to the greater decentralization of purchasing—a plan which was rendered possible by the "Petit cash account" system then allowed to administrators whose work would be expedited thereby.

The delay in official work due to the fact that the present authorized personnel on a permanent basis is not sufficiently large to meet the exigencies of the service was well illustrated in our board, for we have lost our bacteriologist twice within less than 10 months and have been without a professional bacteriologist for a total of about three months. The bureau has done everything humanly possible to help us to meet the situation thus developed, but you can imagine the upset in a bacteriological research problem when one investigator not on a permanent status had to be released because of sound administrative reasons before his problem was completed, and when the bureau, because of limited personnel, saw no alternative and was compelled to take from us his successor—an excellent man—just after he had worked himself into his problem.

Much has been said in the public press about the expensive administrative methods in Government service. So far as the Public Health Service is concerned, as I look back over this past year, with the difficulties that arose in a small unit, I marvel at the fact that the Surgeon General, with his major unit and all of its many wheels, has been able to keep his machine running under the circumstances which faced him.

As stated a moment ago, these remarks are a frank statement of facts and are not to be interpreted either as a complaint as to conditions or as an apology for the point that I am about to report to you less complete results to-day than I had promised myself a year ago.

A. GROUND-WATER POLLUTION.—At your last conference I reported to you that a new and extensive experiment in ground-water pollution was being planned. Through the courtesy of the War Department, the board obtained the use of a very isolated portion of the Fort Caswell Reservation near Southport, N. C. At that place we started certain studies looking to the pollution of the ground water with typhoid fever, *Bacillus coli*, and uranin. I had fully expected to give you the summarized results at this meeting, but all I can do is to lay before you certain details.

We have a mass of data on the bacteria in the ground water, based upon a study of numerous samples taken under a rigid laboratory technique, but the bacteriologist who did the work was suddenly transferred in an emergency to other duty and it will take long and many hours to work up his notes, and a portion of the work must be delayed until a satisfactory successor is found. There are, however, several points in connection with the study which will be of practical interest to you.

(1) *Eaton's tube rack.*—While Acting Assistant Surgeon Eaton was with us as bacteriologist, he devised a very ingenious tube rack to reduce labor in culture tests on the *Bacillus coli* group, especially for typhoid, but which is of course applicable to other tests also. The device is along the general line of the apparatus described by Stimson and Neill (1918)[1] and used in testing disinfectants. We have found that it is a time-saver, hence a money-saver, and if it is new to you I recommend that you give it a trial. A sample rack (Figs. 1–2) is before you for examination.

This rack is made of galvanized iron and contains 20 sets of 6 culture tubes each (or, if one prefers, 6 sets of 20 culture tubes each), but with a common cotton plug for all 120 tubes; thus there is a great saving in the work as compared with plugging and unplugging each tube separately. For purpose of inoculation, the metal rack is placed at an angle in a wooden or a metal frame;

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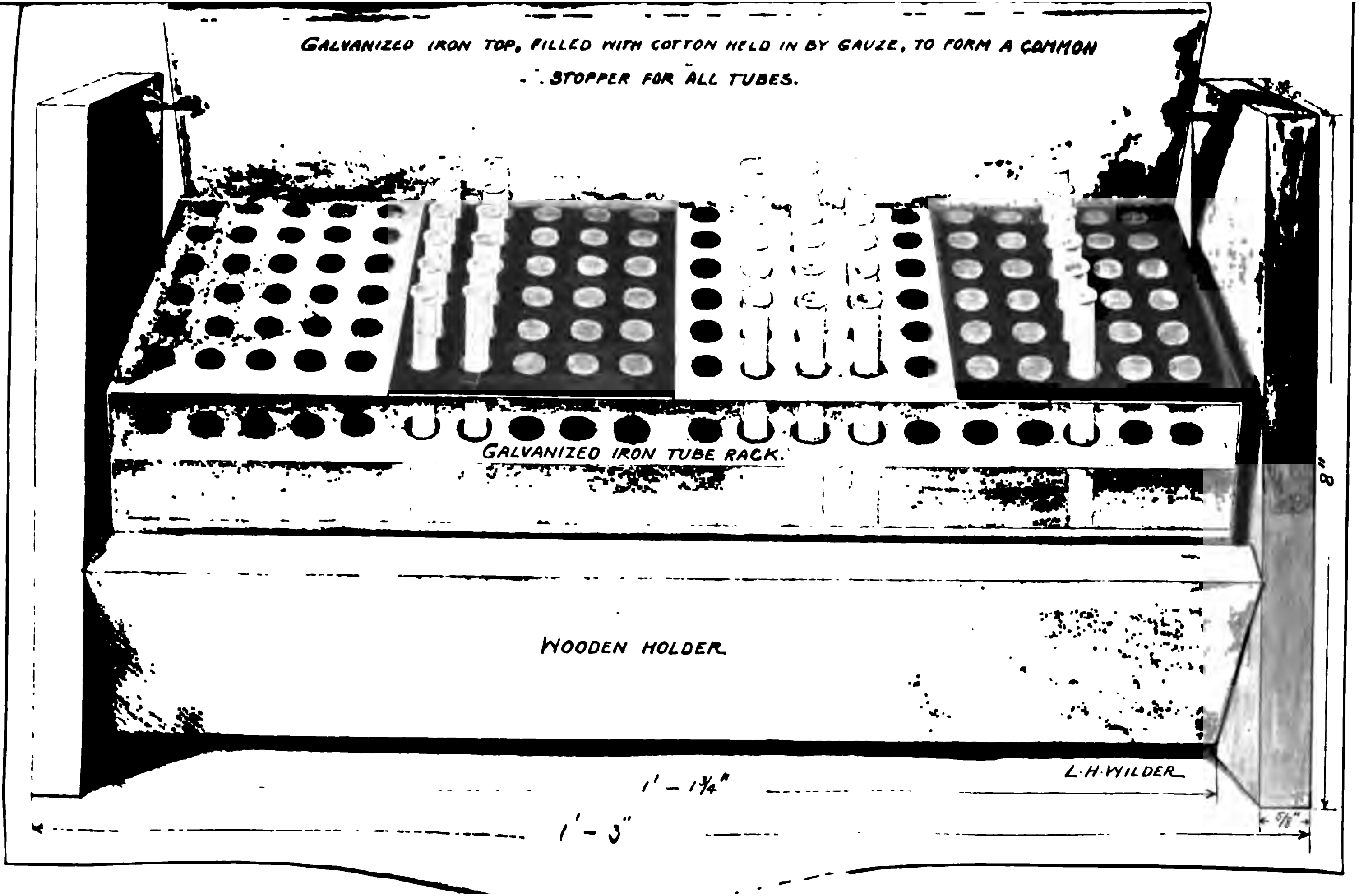
[1] Public Health Reports, 1918, v. 33(15), Apr. 12, 529–539.


GALVANIZED IRON TOP, FILLED WITH COTTON HELD IN BY GAUZE, TO FORM A COMMON STOPPER FOR ALL TUBES.
GALVANIZED IRON TUBE RACK.
WOODEN HOLDER
L. H. WILDER
8"
1' – 1¾"
1' – 3"
⅝"

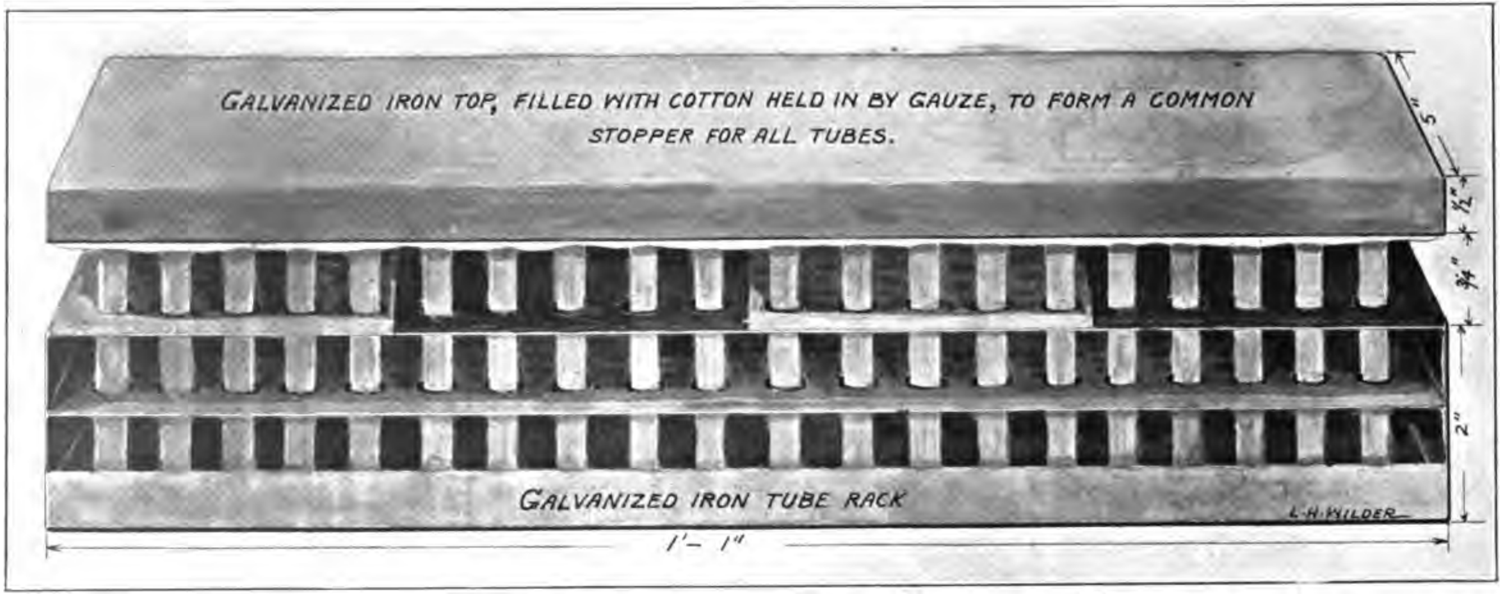

GALVANIZED IRON TOP, FILLED WITH COTTON HELD IN BY GAUZE, TO FORM A COMMON STOPPER FOR ALL TUBES.
5"
½"
¾"
2"
GALVANIZED IRON TUBE RACK
L.H. WILDER
1'– 1"

FIG. 2.—TUBE RACK, CLOSED.

the cover is raised and fastened but at an angle which shields the openings of the tubes from above. When the tubes are inoculated, the cover is pressed tight, thus plugging all tubes at once, and the rack is placed in the incubator, thus giving synchronous results on 20 samples for reaction with lactose, dextrose, maltose, mannite, litmus milk, and saccharose, and substituting two movements (one for plugging and one for unplugging) in the place of 240 movements (120 to plug, 120 to unplug).

(2) *Crohurst's pipette wells.*—The problem of obtaining underground water samples by a surgically aseptic technique, and at not too great expense, has at times presented difficulties, especially in view of the great number of tests that are necessary. Our sanitary engineer, H. R. Crohurst, has now solved the problem so far as our work is concerned, for he has devised two types of wells (Figs. 3–4) which are practically surgically aseptic pipettes. One of these types is so simple in its installation that a few days ago, under very favorable circumstances as to soil, he, with one helper, installed 21 of them in about one hour. The time necessary for installation varies, of course, with the nature of the soil and the depth of ground water.

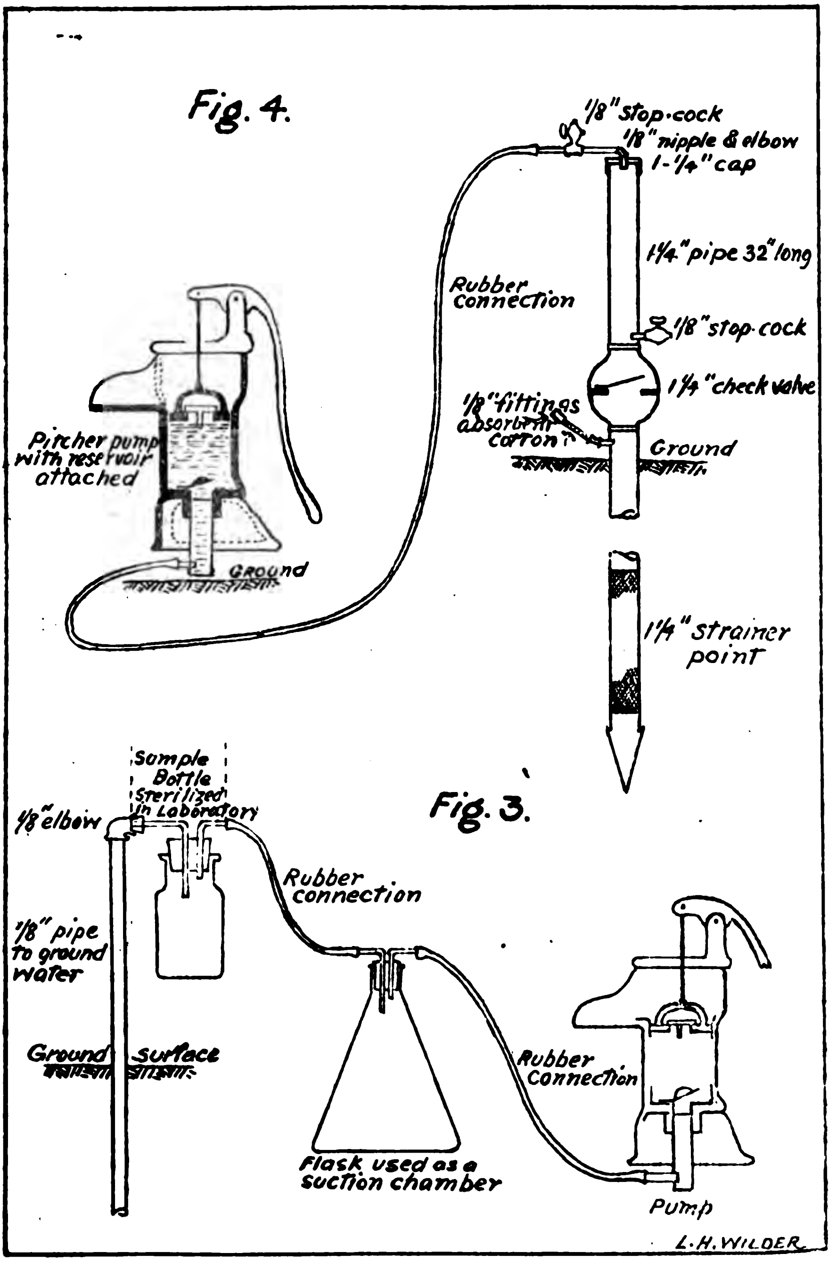
Smaller pipette well: The well itself (fig. 3) consists simply of a one-eighth inch pipe of the desired length, with a copper screen at the lower end and an elbow with screw plug at the upper end. The hole in the ground is made by sinking a plunger. For this purpose we use either a one-eighth inch pipe threaded at one end on which a point is screwed, or if the resistance of the ground is greater we use a solid iron bar. This plunger is forced to a desired depth, then cautiously withdrawn, and the well pipe is inserted. The lumen of the well pipe can be chemically sterilized in the laboratory, if desired; the plunger and the outside of the well pipe can be flame-sterilized in the field by use of a plumber's torch; thus, the well can be sunken bacteriologically sterile from air contamination. If by chance the screen becomes plugged, an automobile tire pump is attached at the upper end of the pipe and the screen is soon freed from obstruction.

To draw the samples, Crohurst has adapted an ordinary pitcher pump in the manner shown in the diagram. You will notice that the pump is screwed on a short blind-pipe which serves to hold the priming water. This pipe is tapped by a one-eighth inch short lateral pipe, connected by a rubber hose with one of the two glass rods extending through the rubber stopper of a retort. The second glass tube of the retort is connected with a rubber hose to one of the two glass tubes perforating the rubber stopper of a sample bottle, and the second glass tube of this bottle carries at its end a small perforated rubber stopper. The latter is then fitted into the elbow of the pipette well after the screw plug has been removed. It is obvious that with proper precautions as to sterilization an absolutely noncontaminated specimen can be taken.

This device is proving of great value in our work, and it requires no special imagination to see that it can prove very useful in making temporary sample wells for various explorers and possibly wells for drinking water for some camping parties. It certainly opens up increased facilities in exploring ground water.

Larger pipette well: Mr. Crohurst's first important improvement on the pitcher well, from a standpoint of sampling ground water, is shown in Figure 4.

The wells consist of a 1¼-inch pipe, with strainer point on the end driven into ground water, similar to the ordinary driven well. On the top of the well pipe at the surface of the ground there is placed a 1¼-inch check valve, opening upward, above which is a length of 1¼-inch pipe 2 feet 8 inches long, capped at the top. This forms a reservoir above the valve. The cap at the top of the well is tapped and fitted with a one-eighth-inch nipple and elbow, into which a plug is screwed for protection between times of sampling. Just above the check valve in the riser pipe there is placed a one-eighth-inch brass stopcock, through which samples are drawn. Below the valve there is a one-eighth-inch nipple, elbow, and short straight length of pipe, the end of which is



fitted with a valve to permit the water to fall back into the well to the water table after the sample has been taken. In the straight length of pipe absorbent cotton is placed, through which the air passes that enters the well.

In operation the plug in the one-eighth-inch elbow at the top of the pipe is placed in the coupling in the one-eighth-inch fitting below the valve. The suction of the pump shown in Figure 3 is screwed into the fitting at the top and the pump operated in the usual manner, which raises the ground water into the reservoir above the valve. The weight of the water above the valve closes the valve and holds the water in the reservoir. The sample is taken from the one-eighth-inch brass stopcock. After the sample is collected the plug is removed from the fitting below the valve, and this allows the water in the casing to fall back to the water table, and the plug is then placed in the fitting at the top of the pipe, after which the well is entirely closed until the next time for sampling.

Our pits and wells are at present arranged in 6 groups, and we expect to add 12 additional groups in the near future.

Group 100 is used for a pure typhoid experiment, to test out especially the viability of our cultures of *Bacillus typhosus* in competition with the subsoil and ground water bacteria in this particular soil. Unfortunately our finances do not permit us to subsidize a typhoid carrier, so that of necessity we must at present use pure cultures of typhoid.

Group 200 is used as control.

Group 300 represents a combined *B. coli* plus *B. typhosus* experiment.

Group 400 is used for special observations on the water-table changes.

Group 500 is used for a combined uranin and *B. coli* test, which has recently been started. In this experiment we expected to bury large quantities of uranin and of human feces directly into groundwater, but as a result of the reduction of the size of the Army most of the soldiers from whom we expected to draw our supply of excreta were sent away from the fort, so that we have been forced to use cow dung thinned with water, a substitution which in this particular test seems to be justified despite the fact that it is Hobson's choice. Prior to dosing, hundreds of examinations of the ground water and of the natural soil and subsoil had, according to Dr. Eaton, failed completely to show the presence of *B. coli* in the fields where we are working.

On the fifth day, after the first (April 25, 1922) dosing of the pit with diluted cow dung plus dissolved uranin, a rain resulted in raising the water table 3 inches, but up to this day (April 25) the result of the experiment was negative.

On the seventh day uranin was recovered from a well 12 inches away from the trench, while 20 other wells, all within 4 feet of the infected trench, were uranin negative, and all 21 wells were *B. coli* negative.

On the eighth day uranin was recovered from 6 wells up to 32 inches from the fecal trench; *B. coli* seemed to lag somewhat behind the uranin, but it was recovered from 4 of the 6 uranin positive wells and up to a distance of 24 inches from the trench.

On the ninth day—namely, after eight days' work—uranin was recovered in 9 wells spaced 12 to 48 inches from the trench, while 21 wells from 12 to 48 inches were uranin negative; 1 well, which had been uranin positive, but *B.coli* negative, on the seventh and eight days, and which is 32 inches from the trench, became *B. coli* positive on the ninth day, thus showing a lag of two days. Beginning with this day, wells which had been found both uranin and *B. coli* positive were not as a rule reexamined for *B. coli*.

From the tenth to the nineteenth day (May 13, 1922) no additional well became positive either for uranin or for *B. coli*, although one well (28 inches from the pit) which had shown positive for both uranin and *B. coli* became negative for *B. coli* while it still contained uranin.

Dry weather followed from the ninth to the twentieth day; progressive pollution could not be proved, but we awaited with interest the effects of the next rain.

On the seventeenth day events took a sudden and unexpected turn. The water samples were entirely negative beyond 4 feet from the trench, but a departure in the routine disclosed a small greenish spot in the capillary fringe above the water table 10 feet from the trench; a soil sample from this spot was washed in water and this proved positive for uranin. Borings were immediately made at various points and it was found that the uranin was present in the capillary fringe above the water table and outward away from the trench. On this (the seventeenth) day five soil samples from the capillary fringe were uranin positive; three of these were presumptive *B. coli* positive at 7½, 8, and 10 feet and two were presumptive *B. coli* negative at 10 and 11¼ feet, respectively: four samples were both uranin and *B. coli* negative at 7½, 12½, 12½, and 15 feet, respectively; all of these samples were taken in the downhill direction from the pit. Confirmation reports on the *B. coli* presumptive are not yet in my hands.

On the eighteenth day two soil samples 1 and 2 feet, respectively, on the uphill side of the polluted trench were negative both for uranin and for *B. coli*.

On the nineteenth day three soil samples from the capillary fringe on the downhill side, and 6, 10, and 12 feet, respectively, away from the polluted trench were uranin positive, while four samples from the fringe 2, 4, 8, and 14 feet, respectively, downhill from the trench were uranin negative. Of the three uranin positive samples, two—namely, at 6 and 10 feet—gave presumptive positive test for *B. coli* within 24 hours, but the confirmation tests are not yet completed.

On the twenty-first day a soil sample from the capillary fringe 17 feet away from the trench was uranin positive, but the water layer below it was uranin negative, while a well 7½ feet from the trench was uranin positive.

The uranin band was approximately 2 inches thick, intensely green at some points, scarcely discernible at others, but easily brought out prominently in either of two ways, namely: First, by washing the sand in a bottle or test tube; second, by shaking the sand in a bottle the inside of which was slightly moistened with condensation water. The washing method is the better. At a time when the uranin was found in the capillary fringe 12 feet from the trench it could not be located in any of our wells more than 4 feet from the trench; up to this time *B. coli* was traced as far away from the trench as 32 inches in the wells, and according to the presumptive 24-hour test *B. coli* was present in the capillary fringe 10 feet away from the trench.

Possibly it is known to you that uranin appears in this way in the capillary fringe and can be found in the soil even when the ground-water examination is negative. It is, however, a new point for us and it opens up a number of very practical questions. We have had experiments in which our uranin has simply disappeared from view and has not been found later; we had one experiment in which the uranin was lost to view for nine months and then suddenly and unexpectedly appeared in our wells. We have been at a loss to know what had happened, but now the thought suggests itself that the uranin might have entered the capillary layer above the ground water and had later been washed down by a rise in the water table.

All sorts of theoretical questions arise; for instance, did this uranin actually travel laterally in the capillary fringe, or was it left up there by a decline of the ground-water table due to sudden evaporation and other factors, but not showing in our present water-table wells? In this latter event, why did the uranin not show in the ground water as far away from the trench as it did in the capillary fringe, or why was the green band only about 2 inches in depth?

Obviously the significance of these observations on the presence of uranin in the capillary fringe remains for the moment sub judice as applied to the spread of bacterial infection. We had not considered the capillary fringe (in comparison with the water table) as a practical factor in the lateral spread of infection, although we had considered it in connection with the vertical spread down to the water table. But it seems clear that the capillary fringe must be studied in connection with the problem of lateral spread.

One deduction of distinctly practical importance is justified from the results thus far obtained, namely, the point is absolutely beyond doubt or question that it is possible to obtain a negative uranin result in a well but a positive uranin result in the moist soil in the immediate vicinity, namely, in the capillary fringe, above the water table, within 3 inches of the negative well. The practical question now arises: How far can the capillary fringe carry uranin and bacterial infection from a point of pollution?

Again, our observations show that because of the irregularity and raggedness of the uranin movement (which resembles an irregular cloud rather than a uniform sheet) a given well can be negative because the uranin escapes it, but a positive uranin result may be obtained on the same day from a well 6 inches farther removed from the point where the uranin was inserted.

We are using the uranin at present only as a guide to show us where to take our water samples. It is altogether too early for us to generalize on the practical interrelation between uranin and bacteria. All I am willing to say at present is that in the early part of this experiment *B. coli* lagged some behind uranin, for instance, on the eighth day a well 32 inches away from our pit showed *B. coli* while a well 48 inches away showed uranin but not *B. coli*; and that indications are not entirely lacking that both infections had traveled diagonally rather than at right angles, therefore that the actual distance may have been greater than 32 and 48 inches, respectively. Further, a well which was uranin positive on the seventh day did not show *B. coli* until the eighth day; and a well which was uranin positive on the eighth day did not show *B. coli* until the ninth day; on the other hand, three wells which showed uranin positive on the eighth day confirmed as *B. coli* positive for the same day.

Group 600 is a repetition of the experiment of Group 500, but at date of writing we have had no rain since the dosing, and there is nothing at present to report, for all examinations have been negative.

It is becoming more and more obvious to us that our study demands a more intimate knowledge of the ground water with its many complicating factors, and on this account we have recently obtained the cooperation of the Ground Water Division of the United States Geological Survey in a study of our problems.

This subject of the water table appears to have been more or less prominent in the subconsciousness of the men who have been writing regulations for the construction and location of privies, but it seems clear that we know altogether too little about this factor in its influence on sanitation, while proof is present that even when there is a flow of ground water in a given direction negative results at a given spot are not a definite proof of negative conditions one or more feet away.

Despite the natural feeling of hopelessness which arises when we consider the theoretical possibilities as to the influences of ground water on the problems of excreta disposal, it would be well to recall that the rural districts of the country at large have unconsciously been making a nation-wide human experiment along this line and that typhoid has been showing a decrease instead of an increase. Further, in view of the increased knowledge of the past 15 years in respect to human "carriers" of typhoid, the thought lies near that our remaining and unaccounted for typhoid index can not possibly be attributed wholly, and perhaps not even in major part, to ground-water pollution. Despite this thought, however, it would be unwise to forget that we must prepare even for explosive outbreaks and the exceptions as well as for the rule.

B. VIABILITY OF PROTOZOAN CYSTS AND OF WORM EGGS.—From January 29 to March 5, 1920, we buried at Wilmington, N. C., under different conditions, especially in 17 sawdust pits, large quantities of human excreta containing spores of *Protozoa* (notably *Endamoeba* and *Giardia*) and eggs of parasitic worms, especially two kinds of thin-shelled eggs (hookworms and *Hymenolepis nana*) and two kinds of thick-shelled eggs (*Ascaris* and *Trichuris*).

The examinations made in May 1922, failed to show any recognizable spores either of *Endamoeba* or of *Giardia*, or any recognizable eggs or larvæ of hook worms (*Necator*). But recognizable eggs of *Hymenolepis*, *Ascaris*, and *Trichuris* are still present. Preference was shown to the smear method over the flotation technique, despite the fact that the latter is much less tedious. Not a single live egg of any of these three species of worms has been found, but patient and tedious search has revealed dead ova as follows *Ascaris*, 1,231; *Trichuris*, 40; and *Hymenolepis*, 5. In nearly all instances the degeneration of the protoplasm was extreme; in only one instance (an *Ascaris* egg) was it only slight.

Accordingly, present evidence is to the effect that under the climatic conditions that have obtained at Wilmington during the past two to two and one-fourth years, all traces of the spores of *Endamoeba* and *Giardia*, and of the eggs and larvæ of *Necator* have disappeared from the human excreta buried in 17 sawdust pits; further, that the eggs of *Ascaris*, of *Trichuris*, and of *Hymenolepis nana* have died. The thought naturally occurs to all of you that the fermentation in the excreta has been one of the chief factors, if not the chief factor, involved in this destruction of infectious material.

Bacteriological tests made of 17 samples of the buried excreta showed that *B. coli* was still alive.

PUBLICATION.—It has been the policy of the board to refrain from issuing bulletins, but there are some phases of the work in respect to which we have data that, it is felt, will be of use to you as matters of reference. Accordingly, the chairman is at present editing a bulletin which will be submitted to the bureau for publication. This will not contain final deductions in respect to all phases of the subject of excreta disposal, but will give you in available form certain data that have been of practical value to us and which we hope will be of use to you.

In summary, due to circumstances beyond our control, my report to you this year is less complete than I had hoped, but it is possible to present to you the following:

(1) Doctor Eaton has been using a tube rack which reduces tremendously the routine labor in laboratory tests on the *Bacillus coli* group, especially *B. typhosus.* This should result in a distinct economy in laboratories.

(2) Mr. Crohurst has developed two pipette wells which have revolutionized our method of taking water samples. The smaller pipette well, in particular, is destined to be of extensive use in a study of ground water, not only by us but also by others. It also comes into consideration as part of the equipment of exploring parties which may wish to safeguard their water supply and who are

traveling in a region where the water table is within reach of the air lift, namely, not more than 30 feet. It is inexpensive and practical.

(3) In a combined uranin and *Bacillus coli* experiment the extension of *B. coli* may lag behind that of the uranin, at least in some cases.

(4) Although a well shows a negative uranin result, the capillary fringe above the water table in the immediate vicinity, even within a few feet, may show a uranin positive result. It would therefore appear that in using the uranin test we must be prepared to modify the present generally used technique and take soil samples from the moist capillary fringe as well as water samples from the well, especially in case the latter is uranin negative.

(5) A given well may be uranin negative, but another well located a few inches away may be uranin positive. As tentative explanation of this fact we advance the point that uranin does not necessarily extend in a regular sheet, as one might suppose it would, but with a very irregular margin such as is seen in a cloud.

(6) Thus far we have assumed that the capillary fringe comes into consideration in the possible diffusion of infection vertically downward, but we have not been seriously impressed with it as a theoretical factor in lateral diffusion. Present indications are that the latter attitude may perhaps not be well founded, and at least that this point calls for study. Further, the theoretical thought presses itself forward whether or not the capillary fringe may not eventually prove to have a tendency to draw infection upward, thus presenting a tendency gradually to eliminate infection from the ground water.

(7) Sawdust pits in which was buried human feces containing protozoan cysts (*Endamoeba* and *Giardia*) and eggs of intestinal parasites (hookworms; *Ascaris*, *Trichuris*, and *Hymenolepis nana*) appear to have lost after two and one-fourth years all evidence of infection with *Endamoeba*, *Giardia*, and *Necator*, and all viable infection with *Ascaris*, *Trichuris*, and *Hymenolepis nana;* but samples from 17 pits all showed presumptive *Bacillus coli* the day I left the South.

(8) Mr. Crohurst has summarized the privy construction data, according to the regulations and official advice, as far as obtained, from the various administrative units of the United States, the Philippines, and Canada, and has prepared the engineering suggestions he feels justified in offering to you.

(9) The chairman is now editing a bulletin for presentation for publication. The manuscript contains data on construction, viability, disinfection, law, and economics, which we hope will be of practical use to you.

(10) Finally, we are looking forward with prayerful hope to the day when the new order of affairs in Government will have become sufficiently routined to permit work to proceed in a less interrupted way and when the Surgeon General will have a sufficient personnel on a permanent basis to render it humanly possible for him to keep men on their details sufficiently long to permit them to complete a job and to write up their notes. As respects finances, I have the honor to report that we have done our best to cooperate in every way with the present desire and demand to reduce Government expenses; we have succeeded in saving money, but this does not mean that the money saved represents an equivalent economy.

Doctor CUMMING. I think I noticed the chief of the ground-water section of the Geological Survey here a short time ago, and we would be glad to have him discuss Doctor Stiles's paper.

Mr. MEINZER. I have been greatly interested in listening to Professor Stiles's discussion, but am not prepared to say much.

Some years ago the water-resources branch of the Geological Survey was actively engaged on sanitary problems relating to water supplies, especially to the pollution of water by industrial waste, but since the Public Health Service took up that kind of work we have done little on the sanitary side of water supplies. We have investigated chiefly the occurrence, quantity, and mineral quality of the natural waters and their recovery and utilization.

Several weeks ago Professor Stiles came to the Geological Survey and explained what he was doing, and that was the first I had heard, so far as I remember, about this experiment. I at once became interested, because it has for a long time been felt that very little is actually known about how far bacteria will be carried in ground water. I went to Fort Caswell with Professor Stiles and spent several days on the geologic and hydrologic problems of the experiments in progress there. Since then Miss Dowell, one of the survey geologists, has been assigned to Fort Caswell for a month to help along the lines of hydrology. This action was taken because it was felt that if the results of this experiment are to have general application, it must be closely correlated with the geology and hydrology. I have great faith in the value of cooperation in scientific research. In nearly all of our ground-water work we cooperate with some Federal or State organization. I hope that this informal and very pleasant cooperation with the Public Health Service will be productive of some good.

The difficulty about the whole matter is that we are dealing with such exceedingly complicated conditions. If there were just one uniform set of conditions careful tests could be made and the problem could be definitely solved. But the rock formations are exceedingly complex and variable in texture and structure—even more so than appears to the eye. The sand at Fort Caswell, where these experiments have been going on, presents about as uniform conditions as will be found anywhere. Yet when the water percolates through this sand it moves, as Professor Stiles has said, like an amoeba, not because it has life but because it is much less uniform in texture and permeability than one would casually suppose. Not only the texture and structure but also the hydrologic conditions are complicated. The position and slope of the water table, and the intake, movement, and discharge of ground water are all of essential importance in this problem, but they differ from place to place and may change radically with the seasons or even with a single rainstorm. Hence, the results of a bacteriological experiment without precise observations on the geologic and hydrologic conditions can not be applicable in other areas.

The conditions at Fort Caswell are almost the worst conceivable for the movement of bacteria. The water-bearing material is a uniform sand, without any joints or fissures such as are common in the harder rocks. The water and anything that it carries has got to go through the comparatively small pores of the sand. There is, of course, plenty of sand that is finer than that at Fort Caswell, but if it is much finer you can not make a successful well in it. Hence, whatever results are obtained at Fort Caswell will be not average but nearly minimum results. If it is found that bacteria will be carried a certain distance under these conditions, we will, in general, have to apply a very large factor of safety.

This [indicating] is quite as much a surprise to me as to Professor Stiles. This band of green is several inches above the water table and above where the water table has been at any time since the experiment was started. It is puzzling to explain how the uranin has got past the test wells without being detected, and is found in the capillary fringe beyond the wells. The uranin has traveled in the direction that the water table slopes, and hence in the direction the ground water is moving. You will notice that no uranin has been found either in the ground water or in the capillary fringe on the upgrade side of the pit into which it was placed. It has traveled only in the direction that the ground water has been moving.

In this locality the water table is only 3 feet below the surface. Consequently, the water rising by capillarity will evaporate, and as it evaporates new water will be drawn up by capillarity to take its place, as kerosene is drawn up in a lighted lamp. Hence there is a constant upward movement of water through the capillary fringe. If you go to a place where the depth to the water table is 25 feet, the water will rise only a few feet by capillarity, according to the texture of the material, and will be a long ways from getting up to the surface where it could be evaporated. Consequently, the water in the capillary fringe above the water table will remain stagnant. It is quite likely that the green bands of uranin in the capillary fringe are due to the upward movement of the ground water and that where the depth to the water table is so great that there is no ground water discharged into the atmosphere the conditions are different. That question can be very easily put to the test.

The work that has been done by this board has, in my judgment, been exceedingly thorough and painstaking. No effort has been spared to make the results decisive and conclusive. Yet it seems that it will be necessary to make still more specific observations in order to corral the uranin and the bacteria effectively. As Professor Stiles pointed out, some of these wells were put down just to the water table and some to a level 1 foot below, some to a level 2 feet below, etc. They were put in almost every possible position to intercept the ground-water drainage. A very serious attempt was made to catch the uranin if any went by. Nevertheless, it got past those wells undetected and was later found in the capillary fringe farther on.

It seems to me that this experiment is very significant. It relates to a problem of great practical importance on which we have hitherto had very little satisfactory data. I admire and applaud the thoroughness and persistence with which the work is being done. I sincerely hope that the investigation can be carried on another year, or a few more years, if necessary, until the experiment is really completed and this difficult but intensely practical problem is as definitely solved as is possible.

Doctor Cumming. I am sure that we all appreciate the discussion of this paper. I will tell you, as a matter of interest, that Doctor Stiles mentioned the amoeba in connection with dysentery. Some alarming reports came out 18 months ago about troops having brought an enormous amount of dysentery back. It came from an authoritative source; but, under Doctor Stiles, we have had thousands of specimens sent in and, fortunately, we can report negative results so far as we can find out. Doctor Stiles will make a final report on it before long.

Is there any discussion of this paper?

Doctor Pierce. I would like to suggest that you extend the courtesy of the floor to Mrs. William Tilton for five minutes. She has some information in regard to the value of comparative data, and I am sure that it will be very interesting.

Doctor Cumming. I am sure we will be glad to hear from Mrs. Tilton.

VALUE OF COMPARATIVE DATA.

Mrs. Tilton. According to records taken from 37 life insurance companies, the country was never so well as in 1921, and I believe seldom so good. We have made a survey of Massachusetts comparing the last two economic depressions, 1915 and 1921. The latter depression has been much worse in Massachusetts, and yet, even so, the decreases in 1921 over 1915 are marvelous.

	Per cent decrease.		Per cent decrease.
Total arrests	15	Deaths from Bright's disease	9
Arrests for drunkenness	43	Deaths from pneumonia	51
Penal population	51	Deaths from tuberculosis	23
Indoor relief	57	Suicides	9
Cases of nonsupport	18	Deaths from alcoholism	47
Deaths from cirrhosis of liver	47		

I wish we might get data like this sent to us from all the State boards of health of the country, with reasons why we have these decreases, as far as they can be gauged. We all want to help the health work of the country, and we can do it more intelligently if we constantly study what is happening through getting in reports and through trying to draw conclusions from the reports of just what is helping. We will send you a questionnaire, and I hope you will fill it out, and then we can publish it and send it through the women's organizations of the country that they may see what work is telling and be more eager to keep at the work and more intelligent as to what work to stress.

Doctor CUMMING. Doctor Creel will report on anthrax.

ANTHRAX.

Doctor CREEL. Mr. Chairman, ladies, and gentlemen, presumably ever since there has been anthrax infection among animals there have been associated with it human cases, more especially in certain groups brought in contact with these animals—drovers, stablemen, butchers, abattoir workers, and, in England, wool sorters. Formerly these cases had been regarded as clinical curiosities for the bacteriologist or the clinician to write about, but more recently the occurrence of human anthrax has become of human health interest and concern.

In 1916 the commissioner of health of the State of Massachusetts reported a series of some 20 or 25 cases of anthrax attributable to infection in a consignment of dry hides originating in Hankow, China. When you refer to Hankow or Hongkong or Canton you include several hundred square miles of China, because hides are merely assembled at those maritime ports. Previous to that time the Public Health Service did not give any administrative attention to the prevention of the introduction of anthrax, feeling that it was a subject adequately covered by regulations formulated in the Bureau of Animal Industry, Department of Agriculture, and issued as joint regulations by the Secretary of State and the Secretary of the Treasury. When these cases were reported, it became apparent that there was some defect in precautionary measures, either fundamental as to the technical regulations or some defect in their enforcement. A conference was held with the Bureau of Animal Industry, and it developed that the regulations contemplated that all hides from foreign ports should be covered by a certificate either to the effect that they had been disinfected or otherwise had come from a territory in which anthrax was not prevalent. There was one technical defect in the regulations, and that was the provision for disinfection for 30 minutes, one to one-thousandth bichloride solution, which was inefficient, and in addition to that it was the general practice that instead of immersing the hides they were sprinkled. The referred to consignment of hides from Hankow was accompanied by a certificate of disinfection. Even before that time the Bureau of Animal Industry had considered the revision of the regulation.

The Bureau of Animal Industry formulated and issued on January 1, 1917, new regulations, which appeared to be technically sufficient. I have a memorandum from the Chief of the Bureau of Animal Industry giving in detail the exact procedure as to the treatment of hides and measures for the prevention of the introduction of anthrax, so far as hides are concerned. I will read this memorandum and give you a better idea of what is being done.

(Doctor Creel thereupon read the memorandum referred to.)

That is the statement of Doctor Mohler, Chief of the Bureau of Animal Industry. There is no question about the necessity for the enforcement of appropriate precautionary measures. It is a question of where they should be applied. The foreign port of embarkation is where it should be done, but it will be frankly admitted that, so far as the Public Health Service is concerned, we would not be able to station at all the ports in the world inspectors to see that the work is done properly.

It is contended by tanners that unless the tannery process immediately follows the disinfection the leather quality is injured or destroyed; and this is agreed to by experts of the Bureau of Animal Industry. It means that if we attempt to enforce this disinfection at foreign ports 30 per cent of our leather supply would be diverted to other markets, and this would seriously disarrange the leather industry of the United States.

So far as the disinfection at the port of arrival is concerned (at the quarantine station), the same objection would apply as to injury to the hide, and the protection to persons in the United States would not be materially greater than if the disinfection were done at the tannery. The hides would be taken from the ship to the quarantine station and the handlers would be exposed. It seems that after thorough investigation the only practical solution is in disinfection of hides at the tannery, and the State authorities should cooperate in seeing that efficient disinfection be performed at the various tanneries. That applies to the anthrax situation as far as hides are involved.

There have been a large number of cases of anthrax due to infected shaving brushes. I have no figures as to the exact number.

I might also say, reverting to anthrax from hides, that a considerable percentage of cases reported during 1915, 1916, and 1917 were due to domestic infection. In 1915, out of 40 cases, practically none of them was attributed to imported infection, and of the 60 in 191 only 25 in Massachusetts were due to imported infection. That is an additional reason why there should be disinfection at the tannery

The shaving brush is an entirely different proposition, and when it became apparent that there were a number of cases occurring from the use of infected brushes imported from the Orient the foreign quarantine regulations were amended and also the interstate quarantine regulations.

The United States quarantine regulations were amended as follows:

Foreign quarantine regulations.

(126) Shaving brushes or lather brushes destined for shipment into the United States shall be made only from hair or bristles, known to be free from anthrax spores.

(127) Unless known to be free from anthrax spores such hair or bristles, before being made into shaving or lather brushes, shall be disinfected by one of the following methods: (*a*) By boiling for not less than 3 hours; (*b*) by exposure to steam under not less than 15 pounds gauge for not less than 30 minutes with a preliminary vacuum of at least 10 inches; (*c*) by exposure to streaming steam for not less than 6 hours.

(128) Consignments of shaving brushes of foreign manufacture shall be accompanied by a consular certificate containing a statement as to the prevalence or nonprevalence of anthrax in the territory from which the brushes emanate and also to the effect that the materials entering into the manufacture of the brushes have or have not complied with the requirements of these regulations.

Interstate quarantine regulations.

(14) No person, firm, or corporation shall offer for shipment in interstate traffic, and no common carrier shall accept for shipment or transport in interstate traffic, any shaving brush or lather brush unless manufactured in accordance with the following regulations:

(*a*) Shaving brushes or lather brushes shall be made only from hair or bristles known to be free from anthrax spores.

(*b*) Unless hair or bristles are known to be free from anthrax spores before such bristles are made up into shaving or lather brushes, their disinfection shall be accomplished by one of the following methods; (*a*) By boiling the hair or bristles for not less than 3 hours; (*b*) by exposing the hair or bristles to steam under not less than 15 pounds gauge pressure for no less than 30 minutes with preliminary vacuum of not less than 10 inches before turning on the steam; (*c*) by exposure to streaming steam for not less than 6 hours.

(*c*) All shaving or lather brushes shall be permanently marked with the name of the manufacturer or with a registered trade-mark in order to insure identification of the manufacturer and enforcement of these regulations.

It will be noted that so far as raw material in shaving brushes is concerned there is no restriction; the restriction applies only to fabricated articles. That provision was adopted because it was felt there was greater security in having the disinfection done in the factories in the United States than in foreign countries.

I might add that more recently there has been introduced a bill in Congress to prohibit the manufacture of shaving brushes from horsehair. It seems to be the consensus of opinion that practically all of these cases attributed to shaving brushes have been due to brushes made from horsehair, and if this legislation goes through it should remove the menace of the shaving brush; otherwise the only other practical way of preventing shaving-brush anthrax is to maintain thorough supervision of all the factories manufacturing shaving or lather brushes.

Doctor CUMMING. I want to state that this subject was taken up at the request of the State health office of Pennsylvania. Is there any discussion?

Doctor DALTON. We have a brush-manufacturing establishment, and when word came out to examine all these establishments for anthrax we sampled everything they had. We found they were receiving bristles and hairs from all over the world, and they were taking the added precaution of sterilizing all material before it was worked up. We sampled everything they had, and got no positive result, but we did discover this: In examining the sterilizing apparatus which they were using they were apparently not getting the results which they desired in the center of it when large quantities were used. We called attention to the fact that their sterilizing apparatus was not working satisfactorily, and they proceeded to fix that, so that when we went over it later on we found that they were getting results. The point I want to bring out is simply this: That because a particular manufacturer guarantees a sterilizing apparatus it is not fool proof, and it should be followed up in regard to this particular subject of anthrax.

Doctor CUMMING. Is there any further discussion? Is there discussion of the amendments to interstate regulations?

Doctor MCLAUGHLIN. I would like to say that we are getting along so nicely that we had better leave them alone. We had a lot of suggestions that should have been sent to the committee. There are three or four very good ones, but we had better not do anything at this meeting, in view of this fact, that the 18 States have put the sanitary code into effect, and I suggest that we leave them alone for another year.

Doctor CUMMING. Doctor Williams, of Virginia, wishes to make a statement.

Doctor WILLIAMS. We thought it would be of interest to the health officers to have the discussion in regard to rural health work take place where they have an organized health department. In Arlington County there is an organized health department. It was started a number of years ago in cooperation with the International Health Board, in which the International Health Board and the State paid half of the expenses, the county paying the other half. That lasted for about a year and a half, and then the county undertook to pay the bulk of the sum, and the United States Public Health Service helped us.

We have got in charge of that unit a man trained in the United States Public Health Service, Doctor Cox, who had charge of their work during the war.

As we know, the development in health work is largely due to length and breadth of one man, so the development of this work over there is chiefly due to the splendid work and influence of that health officer whom we were able to get from the Public Health Service. The continuance of this work and its development in recent years has been largely due to the influence and cooperation which sometimes we have been able to get from the Public Health Service, or through Doctor Lumsden's division and Doctor Cox's division. We hope that you will all go over there and see this work.

We have some moving pictures illustrating other features in health work that we want to show you, particularly some malaria work and rural sanitation, illustrated by moving pictures. The Public Health Service has kindly arranged to provide transportation. I think the county officials have given us the privilege of using the courthouse for the afternoon session. We will let the last automobile leave at 2 o'clock. I do not think it would be well for everybody to arrive at once. We want to see the health department office, and the first cars leave at 1.30 and the last leaves at 2 o'clock.

Doctor Lumsden. I think it will be very much better if Doctor Williams will let us go in a body, because the idea is, as I understand it, that Doctor Cox wishes to take only a short tour in the county, and show us certain features of the work, which will last three-quarters of an hour or an hour, before we assemble at the courthouse for the afternoon session, and it will be impossible to say which is the principal thing he wishes to point out. I think of one more thing that Doctor Williams did not mention. The Public Health Service did cooperate in it, and I am proud of the fact. We cooperated to a small extent.

Doctor Cumming. The next papers are exceedingly important—the control of water supplies used in interstate traffic—and it seems to me that they should not be hurried. Is there anybody here who will discuss "Chlorine as a means of assuring the safety of drinking water"? I do not see how we will get through otherwise.

(Mr. Pincus then read his paper.)

CHLORINATION AS A MEANS OF INSURING THE SAFETY OF DRINKING WATER.

The subject of the chlorination of public water supplies is now a most important one for public-health officials to consider. So general and widespread has been the recognition and use of chlorine disinfection as a means of safeguarding public water supplies from becoming an agent for the spread of disease that it has become incumbent on administrative health officials to clarify and formulate their attitude or policy in the recommendation and use of this method of water supply protection. During the last 15 years about 3,000 public water supplies have had chlorination installed as a process for the protection of approximately 30,000,000 water consumers from water-borne disease, and in this same period the typhoid death rate, generally accepted as the best available index of the prevalence of water-borne disease, has been reduced over 60 per cent in the United States registration area. From the experience of so many places and situations where chlorination has been used and the knowledge and study of these results it is now proper, even necessary, that Federal and State health officials determine a deliberate and consistent policy toward chlorination—when it should be recommended, what it should be expected to accomplish, and what part chlorination should have in the general water supply protection program.

The question should be settled whether chlorination is to be looked on to-day as the panacea, the cure-all for dangers from water-borne disease, as it was first acclaimed, or if not, what its proper status is to be in the defense against infection through water supply.

It must be considered well established now that chlorination is not the all efficient, all-effective water purification process which some have looked for, nor is it ever likely to supplant or become a substitute for the older processes of water treatment. It is true that during the war on the battle fronts chlorine, or more properly hypochlorite, disinfection of water was the universal and generally sole means employed for purifying water, so that at the close of the war the chief sanitary officers of the armies of this and other countries held chlorination to have been the greatest single sanitary measure developed. But the circumstances in the armies under war time conditions are so unlike and opposite to normal and peace-time conditions of permanent communities that the former experiences and results are scarcely at all applicable. Chlorination can not properly and should not be looked upon as a complete method of protection to a community from a water supply that is receiving actual pollution. The situation regarding chlorination is somewhat similar to the pasteurization of milk, which is only one line of defense, a supplementary one, after other sanitary barriers against infection have been established.

Examining the chlorination process somewhat carefully, we find that it has certain special features peculiar to itself and to other methods of sterilization. Theoretically it can accomplish 100 per cent purification, i. e., can remove all infection from the most heavily polluted water given sufficient concentration of chlorine and length of contact period. Practically nothing like such a percentage of purification can be reached, even for very brief periods of time. Tastes and odors certain to result from high excessive doses of chlorine, limit the amount that can be applied. Then also the suspended matter in the water appears to have a protective effect against the action of chlorine, lowering the effectiveness of chlorination greatly. The varying chlorine demand of the organic matters in the water, which must first be satisfied before much bactericidal action is obtained, is one factor among many others that produce sudden and wide fluctuations in the continuous efficiency of chlorination. The difficulties at times of insuring the full delivery of the chlorine to the water and the thorough mixing with all the water are influences making for uncertain efficiency. Then, also, the unexpected stoppage of chlorine flow or mechanical breakdown, which may occur and go unnoticed for hours under the best waterworks supervision, during which times the efficiency of chlorine protection is simply zero, is a condition practically wholly peculiar to this process. With filtration or other methods of purification sudden breakdowns of plant are more quickly recognized, and even during such periods the purification remains effective to some extent. And then, above all other factors, making the effectiveness of the process uncertain and irregular over long periods of time, is the exceedingly great dependence necessary upon the human factor inherent in the operation and control of chlorination. Though high technical skill is not needed, however, for anything approaching reliable performance, faithful and frequent attention, practically without possibilities of check by superiors, is required of the operator of the chlorination process. It is entirely beyond reason to expect that such routine, constant attention day in and day out, year after year, can be expected from human agents. It is only necessary to refer to the experience in Milwaukee in 1916, where the night operator permitted the chlorinator to be shut down for only 8 hours, and in the next few days, 50,000 to 60,000 cases of enteritis occurred, followed in a fortnight by about 400 to 500 typhoid fever cases with over 40 deaths, or a similar experience in 1920 on a smaller scale at Pittsburg, Calif., where the chlorinator was off for one day, to show the unwisdom of placing such dependence for protection upon the human factor.

But if chlorination is not to be regarded as the complete treatment process for all kinds of unsafe or polluted waters it is not, on the other hand, to be felt that it has no large place in the program for water-supply protection. It is not my purpose to convey the impression that the chlorination of water supplies is to be looked at in all cases or the majority of cases with suspicion as to the safety and effective defensive barrier that it provides against water-borne infection. Nothing is further from my thoughts. In fact, I fully believe that chlorination has been the greatest single factor to make possible the very high standards that exist to-day for water-supply quality, and in consequence the nearly vanishing typhoid-fever rates now prevalent in our communities.

What, then, is the proper place of chlorination in water-supply protection? In general, I believe the consensus of opinion of sanitary engineers would be that chlorination should be considered a supplemental safeguard, after other and more primary defenses have been established. It may be considered as a reserve line of defense, tremendously important, necessarily available for full effectiveness under sudden emergencies, but not the front and sole line of defense, where it would at all times have to be 100 per cent perfect under the full attack of the enemy. The function of chlorination as a permanent regular part of the purification processes should therefore be limited to acting as a finishing process or factor of safety after all other justifiable means of protecting the water supply and eliminating actual pollution have been efficiently provided. Though it should as a general rule be considered not the primary and sole protection, its great value and general use as a protecting barrier, wherever potential or even remote possibilities exist for unforeseeable contamination reaching the water supply, must be definitely acknowledged and accepted. If it is the aim of efficient present-day water-supply protection to remove every possibility of typhoid fever or other diseases being carried by the water supply, as far as reasonable expenditures permit, then unless a water supply is practically assured for an indefinite period against human pollution (and almost no surface supply whatever is so situated) chlorination should be employed. Wherever a state of irregularity, as Professor Whipple phrases it, is encountered in the quality of a water supply, no matter for how infrequent occasions, there is possible danger and the effective, economical safeguard of chlorination should be used.

Before concluding my discussion on chlorination there is just a word I wish to say about the control of the process. Chlorination without control—control of dosage, analytical control of quality of the treated water, and control over operation—is practically worthless as a barrier against water-borne infection. When first advocated, the importance, extent, and requirements for the control of the chlorination process were not well understood nor emphasized to any extent. Because of this fact there are very many chlorination installation to-day that are giving questionable protection to the communities whom they were installed to safeguard. To-day these features of control in chlorination are tremendously emphasized and are considered of the utmost importance. The dosages of chlorine are made to vary with the particular daily variation in the organic matter in the water and with the bacteriological analyses, the rate regularly being controlled by the excess chlorine test. The chlorine feeding apparatus is given careful, frequent inspections several times daily by conscientious, faithful employees. And finally, the total efficiency of the process is checked daily by the results of bacteriological examinations of the chlorinated water. With such control chlorination, if properly used as a supplemental process in eliminating actual pollution or as a precautionary safeguard against potential dangers, will be found to be one of the most reliable and efficient means science has ever devised for the protection of the health and well-being of mankind.

Doctor CUMMING. Is there any discussion about Mr. Pincus's paper? If not, we will stand adjourned for luncheon, it being understood that the automobiles will be here from half past 1 o'clock until 2 o'clock, and we will go to Arlington.

(Whereupon an adjournment was taken.)

AFTERNOON SESSION, MAY 17, 1922.

(The conference reconvened in Arlington County courthouse at 4.30 o'clock p. m.)

Doctor CUMMING. I think most of the State health officers are here.

The first thing on the program, I think, is Doctor Rankin's report on rural health work. When they hear Doctor Rankin talking, I know the rest will come in. This is a very important report, and I feel that we shall all be interested.

RURAL HEALTH WORK.

Doctor RANKIN. The report of the committee on rural sanitation for this year simply returns to the position this committee has taken for the past two years, and which you have indorsed, which is briefly that the conference recognizes the problems of rural sanitation as problems involving joint responsibility by the Government of the American people, National, State, and county. The second principle which you have indorsed with respect to dealing with the problems of rural sanitation is that of stimulating State activity through national subsidy. The committee has nothing to add that would in any way change the principles upon which you have acted already.

I thought it might be interesting to you to point out very briefly a principle upon which we have been working in North Carolina and which I have referred to in discussing the subject of rural sanitation once or twice before. In some 10 years experience in the development of local health departments, we have found that the adjustment of central or State influence to the development of local interest and responsibility was perhaps the most difficult problem we had to deal with. We have felt that it was necessary to exercise some stimulating influence in the development of county health work, and at the same time we have recognized the danger of going too far with that sort of an influence, going so far that it inhibited or prevented the proper growth of local interest and responsibility. You can not impose salvation, spiritual or physical, upon the people. That is the most difficult problem we have had to deal with. We first tried exercising a good deal of local influence by saying who the county health officers should be. Forty per cent of new health officers drop out in the first two years. Wherever we have been too closely identified with the selection of a local health officer, we have had the responsibility for his failure passed back to us. People have complained to county authorities, and they have said the State board of health sent them down here, and we took them on their recommendation, and the board slipped up, and so have "passed the buck."

Another thing we tried was to formulate a plan for the local health officer and so exercise influence in local work, and by going too far in that direction we have gotten into trouble again. Wherever there has been trouble and failure we are held responsible, because local authorities, when complained to, have said the health officers had to carry out the plans of the State board of health. The problem has been to exercise a directing influence rather than control, and at the same time develop local interest and local responsibility. In bringing that about we have endeavored to reduce local health work to a cost basis.

Those of you who heard the last speaker will remember that Doctor Draper said that in the last five months the picture which he exhibited was shown 105 times to 18,000 people, and the average cost of showing the picture to each individual was 7.2 cents. He has reduced, or at least can reduce, that sort of work to a cost work basis.

We have attempted in North Carolina to reduce every item of work that the local health officer performs to a cost basis. Please make the important distinction in your mind between costs and values. I am not talking about health values. I am not talking about the value of vaccinating against typhoid fever. I am talking about what it cost to do that thing.

A form of report in use in North Carolina shows the health work agreed upon by the State board of health and the local health officers—some 70 or 80 items. It is not supposed that each county health officer can do the whole of it. At the end of the month he will report in the second column on this blank form [indicating] the number of each item of work which he has successfully accomplished. Just to illustrate how the plan works, take the item on typhoid vaccination. There is an established value of 50 cents for each vaccination. That is more than it costs to vaccinate people, but that is the cost value permitted here. Suppose the health officer in a certain county has vaccinated 200 people during the month; he puts that in the second column, and in the third column that would have a total cost equivalent of $100. Every item is worked out on the same basis, so that when the local officer sends this report in at the end of the month you can turn over to the last page and find out the total expenditure in that county during the month. Suppose he spent $600 and suppose his total value is $600, then by dividing the total cost equivalent you get his earnings on the dollar expended, namely, $1. Suppose, on the other hand, that the total cost value was $1,200; then he had earned $2 on every dollar expended. This permits us to reduce the health work of the counties to a common denominator, which the ordinary layman understands.

A man may be working in a county that has 70,000 people in it, and he may have a budget of $25,000. Take the total amount of money spent each month and divide the total cost equivalent and you get what he earned on the dollar. Another man may work in a county of 12,000 people on a total budget of $5,000. Take his total earnings, divide by his total expenses, and get his earnings per dollar expended. In this way you get the comparative efficiency of the man whether he be at work in a large or a small county. It does not make any difference what sort of work he is doing. One may be doing trachoma work and another venereal-disease work. Another man may be doing malaria and typhoid vaccination and medical-inspection work. You reduce the work of both counties to a cost value in terms of the dollar and can make a comparison between the counties irrespective of their size and population and irrespective of the kind of health work which is being carried on.

Our State, like a great many other States, subsidizes local health work. We pay a man so much money a year—$2,500 a year. Instead of conditioning our payment of State funds to the county upon their getting a health officer, upon their adopting a plan which we may or may not approve, we condition the State subsidy on his earning capacity, not upon prospective service he is supposed to render but upon service rendered.

Here is the way the plan works out: If a man earns a dollar on a dollar expended, we pay him $200 a month. We are paying $2,400 a year. Suppose instead of earning $1 on the dollar expended he earns 80 per cent. He would get 80 per cent of $200, or $160 per month.

In this way the State is paying over the money to the county and is absolutely protected against inefficiency. If a man does not earn a dollar for the dollar expended, to that extent he loses State funds. You can guarantee the appropriation committee of your legislature that their money will not be spent for prospective service but only for service that has been rendered.

You may be interested in seeing how this works out. Here are 24 counties that have been tabulated for three months. You will see all the items over there in the first column [indicating], the names of the counties at the top, and you can turn to the bottom of the last row of figures, which gives the earning capacity of each county on the dollar expended. These 24 counties during the last three months expended $47,432.59. They have done $69,234 worth of health work and earned $1.44 on the dollar expended. Looking at the amount of earnings by each individual county, you will see that one county earned $1.22, the next $2.23, the next $2.09, another $1.12, another $1.28, another $1.57, and another $1.01. There are two counties earning only 81 cents on the dollar and one earning only 69 cents on the dollar expended.

One more point and I am through. The question may be raised as to whether the value of the individual items of work are too high or too low. It does not make any difference whether you are dealing with an inflated or deflated currency. In either event you have a standard of measurement—the average earning on the dollar expended. If the health officer falls down in his earning capacity the people will not keep him. He has to earn his money.

Any questions? If so, I shall be very glad to try to answer them.

Doctor STILES. How about your bookkeeping?

Doctor RANKIN. It is a very simple matter. I am glad Doctor Stiles brought that up, because a system of records is necessary in this sort of thing. We have here a little card which is just the size of an ordinary index card which fits in a file case, and if the man has, for example, a case of vaccination, he writes the name, race, etc., and checks typhoid vaccination, or whatever it may be, and that is dropped in his typhoid vaccination folder. It takes him two or three seconds to make out the card.

The understanding with the health officers is that we shall take 200 of these cards and check his records. Ninety-six to ninety-eight per cent of the men are honest, but we have to protect ourselves against an occasional dishonest man.

Doctor STILES. Who audits them?

Doctor RANKIN. The State board of health audits them. We take out 200 cards a year. That is our regulation. If you go before an appropriation committee and tell them that money is needed, and the legislator says, "How do you know," you can give the name and the address, and the place where all the work is done.

for example, a privy being built, or what not. There is enough to verify the work.

Doctor **Garrison.** You base the salary of the local health officer on the results he gets?

Doctor **Rankin.** Yes.

Doctor **Garrison.** What is the average salary?

Doctor **Garrison.** The salaries vary from $2,700 to $4,500, and $600 additional for travel.

A **Member.** What do you mean by results?

Doctor **Rankin.** His earning capacity on the dollar expended.

Doctor **Cumming.** Is there any discussion about Doctor Rankin's paper? Unless there is some objection, it seems to me it will be well worth while, inasmuch as we are out in the country, to clear up the rural health work.

Doctor **Welch.** Let Doctor Lumsden read his paper and discuss them together.

Doctor **Lumsden.** I shall not undertake a comprehensive discussion of Doctor Rankin's paper. The evaluation system which is being tried out in North Carolina is exceedingly interesting and may prove in practice to be of value in the administration generally of cooperative health work. From my present limited knowledge of the details of the system it seems to me to present some definite advantages and some definite disadvantages.

In the course of a fairly extensive and intensive study of rural health activities I have become more and more impressed with the importance of clear perspective in local health work. The most important constant concern of the local health officer should be not what may count most in some evaluation system when recorded on a sheet of paper but what his department can do with the resources available and under the local conditions obtaining which will do most for the prevention of disease and the promotion of health. I can conceive that a local health officer with clear perspective might concentrate for a period of weeks or months his activities along lines which would make little or no showing in some elaborate evaluation system but by so doing lay a solid foundation for big constructive, lasting work, while another, with clouded perspective, might take short cuts to transient success on paper and accomplish little or nothing of lasting benefit to his community.

The program of health work in Arlington County, Va., of which we have had a somewhat sketchy view this afternoon, could not have been carried to its present degree of success, or to any degree of success, if the county health officer had not given a large proportion of his time for a period of about six months to cases in court. Without the work in court the whole program of health activities would have been terminated, but that work in court probably would not have counted as "results" in some of the evaluation systems proposed.

I shall review briefly now the health work in this county. The work was begun in August, 1919, as a cooperative project in which the county authorities, the local Red Cross chapter, the State board of health, the United States Public Health Service, and the International Health Board participated.

The funds provided the first year for the support of this demonstration in rural health work totaled $8,000, of which $4,000 was appropriated by the county government. The appropriation by the county government for the second year of the work was $12,000. The budget for the third (the present) year is about $24,000, of which about $21,700 is provided by the county and $2,300 is allotted from the rural-sanitation fund of the Public Health Service. The funds available now amount to about $1.25 per capita of population, which is the largest I know of for the support of health work in a strictly rural community, and is sufficient for a comprehensive, effective program of health activities under these local conditions.

From the beginning of the work the county health officer has endeavored—as all health officers should—to carry out in logical sequence the different branches of health work needed and feasible—one activity following and dovetailing with another without increasing overhead expense.

Among the first activities concentrated upon by the county health department was the control of soil pollution. You have observed that the county is thickly built up. The area is only 28 square miles and the population is about 19,000. There was no public sewerage system nor public water supply. At a large majority of the dwellings in 1919 open surface, grossly insanitary privies were in use. Typhoid fever, dysentery, and worm infections were prevalent. Under good business management and with remarkable rapidity, box-and-can sanitary privies, septic tanks, and water-tight sewage tanks were installed and a public scavenger service inaugurated. Of the 3,800 dwellings in the county, about 2,000 have been equipped with box-and-can sanitary privies and about 1,600 with either septic tanks, with subsoil disposal of effluent, or with water-tight sewage tanks from which the sewage is pumped. The public scavenger service is more than self-supporting by a margin of profit of over $10,000 annually.

The next activity concentrated upon by the health department was the physical examination of school children and the carrying out of a system of follow-up visits, health games, and general educational measures to secure correction of physical defects found. Health clubs were formed in the school. The general health club of each school competed with the general health clubs of the other schools. Each grade in the school has a health club to compete with those of the other grades in the same school, and in each grade there are a boys' club and a girls' club which compete with each other. As a result of the competition system for health standing, the degree of well-directed enthusiasm for health among the school children of this county is most remarkable. Over 80 per cent of the physical defects found on the first round of examination have been corrected. In three of the larger schools a record of 100 per cent corrections of corrigible physical defects has been made. In none of those three schools can a decayed tooth be found. Think of it! Enlarged or diseased tonsils, adenoids, and marked malnutrition now are unfashionable and are viewed with derision by the membership of the school health clubs. A dentist on the county health department force works all day every day fixing the teeth of and teaching mouth hygiene to the school children. Tonsil and adenoid operations are obtained under contract at a cost of $15 a case at the near-by city hospitals. In each grade in each school there are a boy health officer and a girl health officer. They definitely understand that they are members of the working force of the county health department, of the State board of health, and of the United States Public Health Service. They perform their duties with a zeal and diligence which make some of us older ones feel like back numbers and realize that great are the wonders of democracy.

From the beginning of the work measures to prevent the spread of infection from cases of acute communicable disease have been carried out as rigidly as practicable and invariably have been given priority over other activities of the health department.

In this, the third, year of the work special activities for the promotion of infant and maternity and preschool child hygiene, adult life extension, and tuberculosis control have been well started. At the two baby clinics over 250 babies were examined in the first month of that special activity.

At our annual conferences for some years past I have endeavored to emphasize the advantages of well-balanced, effective, economical, and comprehensive local health service performed under the direction of one whole-time local health officer, so as to have a maximum of work with a minimum of overhead expense.

This work in Arlington County appears to me to demonstrate well the fundamental advantages of such direction of all branches of health work in rural districts. Every public health activity here is carried out under one administrative head. It is a job with a man on the job who knows it. The health nurse engaged especially on infant hygiene work or on school hygiene work may be assigned to other duties from time to time, as the health officer at the head of the unit deems advisable. With all members of the force under one administrative direction, there is at least a chance for economy and efficiency in the public health business. So much for Arlington County.

I have just completed the tabulation of the returns from the State health department on the progress of whole-time local health service in our rural districts during the calendar year 1921. It is exceedingly gratifying to me, and I am sure it will be so to you, to know that in 1921, which was a year of general economic depression, the number of counties or equivalent divisions wholly or in large part rural provided with local health service under the direction of whole-time local (county or district) health officers was increased from 161 to 203, a gain of 42. I think that all of us who have preached and prayed and worked and fought for the common-sense principle of reasonably adequate local public health service under the direction of duly qualified whole-time local health officers should be encouraged from the report of progress in 1921 to hope with reason for great results in this vitally important field within the next decade.

We who from study and experience know something of the administrative principles involved in rural health work should avoid advocating makeshifts which, though at times perhaps offering temporary gains, will result in permanent loss. We should hold to our faith and express that faith with both words and work. If we do not, we shall not do our full duty to those we serve.

Doctor CUMMING. Is there any discussion of this excellent report? To my mind these have been exceedingly important reports.

We do not want to discriminate, but Doctor Park is coming down from New York to-morrow, and has to go back. His paper is a very important one.

If it is not imposing on you too much, I would suggest that we meet at 9.30. I would like to have some expressions of opinion. Suppose we have a motion.

Doctor MCCORMACK. I move that we meet at 9 o'clock.

(The motion was duly seconded and carried.)

Doctor CUMMING. We will meet at 9 o'clock to-morrow morning at the Red Cross Auditorium.

(Whereupon, at 5.15 o'clock p. m., the conference adjourned until May 18, 1922, to meet in the auditorium of the Red Cross Building at 9 o'clock a. m.)

MORNING SESSION, THURSDAY, MAY 18, 1922.

(The conference met at 9 o'clock a. m.)

Doctor CUMMING. The conference will please come to order.

The Public Health Service, as you know, functions under the Treasury Department, and we are fortunate in having with us the

Assistant Secretary of the Treasury, who takes a very active interest in the welfare of the service. Colonel Clifford has been good enough to come here this morning, and will address you, and I take pleasure in introducing Mr. Edward Clifford, Assistant Secretary of the Treasury.

Mr. CLIFFORD. It is related that when Mark Twain was taken to the White House to be presented to President Grant, after the introduction, the President, who had a cigar in his hand, put it in his mouth and began to smoke it. Mark also pulled out a cigar, put it in his mouth, and looked at General Grant. The President then removed his cigar for a moment, replaced it, looked at Mark, and again began to smoke. Mark Twain did likewise, and continued looking at the President. The third time that the President put his cigar in his mouth without saying anything, Mark could not stand the silence any longer; so he shifted his position and said, "Mr. P-P-President, I am em-em-embarrassed. Are you?"

That is the way I feel this morning. As I have said to the Surgeon General, I do not understand why a banker was selected to supervise the United States Public Health Service, but it may be that in shifting the political cards here I got the job which was intended for Dr. Hubert Work, who is now Postmaster General.

However, I am glad to be here this morning, and on behalf of the Treasury, welcome you to this conference. I think we have an efficient United States Public Health Service. As all of you gentlemen know, it has been put to the test during the last three years in caring for the sick and disabled World War veterans, and has not been found wanting. I am not going into that subject except to say that the work was thrown on the United States Public Health Service in March, 1919, without any warning. From that time up until the 1st of May, 1922, when the veterans' hospitals were transferred to the Veterans' Bureau, it gave treatment to over 200,000 disabled World War veterans. There is no question in my mind but that the whole country realizes, more than ever before, the enormity of the task performed by the United States Public Health Service, and I think it will go down in the history of that service, which has been functioning since 1798, as a notable achievement. Now that this problem has been rightfully lifted from its shoulders, I think we may expect much greater things in the regular public-health work.

It seems to me that the United States Public Health Service has two main functions. One is to prevent contagious diseases entering the country through the immigrant and to guard against the interstate spread of disease. It can not be expected that this work will be done by the State or local authorities. This national work will be done just as efficiently as Congress will permit the service to do it For the United States Public Health Service can function only along the lines for which Congress appropriates the money. I trust and believe that Congress will be fair in the matter of appropriations and that the service will have adequate funds to continue that work and bring it up to an even higher standard; in fact, it should do better than during the past three years now that it does not have the responsibility of caring for the veterans of the World War.

I am one of those who believe that the National Government should never do anything which private individuals or local governments can do. You will see that I am opposed to Government ownership of any kind. I am opposed to the National Government usurping any of the powers which should be exercised by the individual or by the State or local governments. That does not mean that I am not in favor of regulation. I believe in private ownership with strict regulation. The initiative of the individual must not be killed. The best service will be rendered to the people of the country where individual initiative is unhindered.

If you read the history of our Government and how it was formed, you know how jealous the 13 colonies were in giving any powers to the National Government. They only gave the United States certain powers and retained all the others themselves. Now, because the Federal Government has functioned rather well and has the enormous resources of the National Treasury back of it, there has been a growing habit on the part of a great many people of this country to run to Washington every time a vexatious problem is presented to them. The result is that there has grown up a strong central Federal Government, which has been gradually closing upon State and local governments in performing local functions.

I think we have gone entirely too far in centralized government, and I think it is time that the people of the country take account of stock, so to speak, to see just where we are drifting. I believe the more thoughtful ones will conclude that we are putting too much of the burden on the National Government and making it do too much of what the States and municipalities ought to do.

I will go so far as to say that I am opposed to the spending of money from the National Treasury in the various States where the only benefit is to the local residents. I am strongly of the feeling that we should be jealous of our local rights, and not let the National Government, just because certain people think it can function better than the local authorities, come in and try to regulate us and do all the police work which we should do ourselves. Therefore, the second function, it seems to me, of the United States Public Health Service, and I know that this is the feeling of the Surgeon General and of his associates, is to be an aid to the local government in solving their local health problems.

On account of the experience and the facilities which the National Public Health Service has, it should do the investigating and the laboratory work and should coordinate all the work which is being done in the various States, and should be a sort of central agency of suggestions, if I might put it that way, to which the local health people may come to get the concentrated ideas of all the men who are doing public-health work. That is the thought the United States Public Health Service has; that you may meet under a central agency which has the machinery to gather together and, to use the word so popular in Washington at the present time, "coordinate" public-health thoughts and the public-health investigations and tabulate the results, so that they may be of benefit to all.

I think the local health problem in Evanston, Ill., where I live, is a matter for the Evanston people to attend to, and we should have a strong public health service there. I think we have. However, the inspiration should come from the Public Health Service in Washington, through the Illinois Board of Health, so that our local health service can have the best thoughts and ideas and get the best results from the investigation that the National Government is making and apply it to our local problems. As a citizen of Evanston, I would resent having a national public health man coming to Evanston and telling us what to do, unless at our request. I am sure under this administration there is no thought of the officers of the United States Public Health Service going to any community and endeavoring to dictate as to the handling of its public-health problems, although we are called upon to do that a great many times.

A college classmate of mine in a distant State recently thought that the health conditions in his town were bad, so he wired me to send a United States Public Health specialist to his town to make an investigation and tell the local physicians what to do. I replied that we would be very glad to cooperate with the physicians in his community upon the request of the board of health of his State; that if his local physicians would put the problem before the State board of health and that board felt that they needed some advice and suggestions from the specialists of the United States Public Health Service in Washington these specialists would gladly be sent. That is the idea I have of the position which the Federal Public Health Service should take on questions of this kind.

We have a hygienic laboratory here where we should make all the investigations we possibly can and give the results to you public-health men from the various States. We should take the literature relative to public-health work which any of you men get out and have it put in permanent shape for distribution to those of you from other States, and we should have frequent conferences, not only national but conferences in the various States. We should furnish specialists on public-health problems to come to your State and address the conferences. When you have particular problems for investigation we should have our national public-health men go to your States, upon your requests, and help you make these investigations and cooperate with you in making your States healthful communities. We want to give you all the practical assistance that we can.

I realize in doing this that the Surgeon General must send out physicians who are men of tact; that they must not be getting in where they are not wanted, and when they do go into your States they must conduct themselves so that there will not be a feeling on the part of the local people that the Federal Government is usurping the States' powers. I recently heard a speaker describe the difference between courtesy and tact. He said a master plumber in Philadelphia was instructing his workmen who went about fixing bathrooms. He told them they must be both courteous and tactful. He said, "If you step into a bathroom and find a lady taking a bath, as you back out of the room you should say, 'Excuse me, madam,' that would be courteous; but if you should say, 'Excuse me, sir,' that would be tactful."

As I said at the beginning, I do not know that there is anything I can say to you gentlemen except to tell you this, on the part of the administration and the Treasury. We are very glad, indeed, that we have such a splendid lot of men and women who have taken up the health problem throughout the country. I say "splendid" men and women because in the year that I have had supervision of the Public Health Service I know what you are doing. I know that there is a lot of hard work and no particular glory in it for you, and not very much money; but if this country is to function properly and not degenerate, we have got to have the interest of high-class men and women in public affairs. Most people, of course, are selfish. We shall never attain the highest plane of civilization in this country if there are not in every community some people who are unselfish and who will do their part for the public good. There are a great many reformers that do not reform very much. They get in the stream and muddle it up, and somebody who thinks straight comes along and steers the proper course.

I find through my supervision of the Public Health Service that the physicians of this country are usually men who think straight. Some one said about you, in paying a compliment to the physicians of the country, that medicine is the only decent profession for a gentleman; but he said you all work hard, live well, and usually die poor.

The physicians of the country can do more good by guiding the people along right living, not only physically but morally and mentally, than anyone else. I am delighted to know that we have so many upstanding men and women who are grappling with these problems all over the United States. Anyone who travels knows how far ahead we are in sanitation and public health compared with other countries, and I think it is due to the fact that there is something about your corps—you physicians and sanitarians of this country—some sense of responsibility to our Government and to our people.

It is fortunate that we have such a lot of public-spirited citizens who are thinking of what they can do for their fellow men and who are spending a good part of their time for the public good.

You State public health officers and sanitarians are doing a wonderful work, and the Treasury, through its Public Health Service, wants to encourage you. You can count on this bureau, with Surgeon General Cumming at the head of it, to do its part in cooperating with you in every way possible. Of course, you must not expect that we can solve all the problems that come up, but we will do our best. We do not expect to come into your field and do your work for you, but we do want to be here with a strong, central, expert, scientific organization which, with your cooperation, will endeavor to solve the public health problems as they come up and make the United States the healthiest place in the world.

I hope that you will feel free to come to see us and to write us and that you will send us the results of your investigations, so that we may have the benefit of your advice and suggestions and cooperate with you in every way.

I thank you for giving me the opportunity of welcoming you on behalf of the Treasury.

Doctor WELCH. The president of the conference, on behalf of the conference, I wish would thank the gentleman for his good American talk. I do not think there is a man in this audience that can't respond most heartily to everything he says and thank him for the angle of view which he tells us that the administration at Washington has. Irrespective of parties, we have all felt in the last quarter of a century that we were tending too much to centralization, and as a representative of the rural districts of this country I wish to thank the Assistant Secretary for what he said this morning in behalf of the conference.

Doctor CUMMING. I am sure we all appreciate very much the Assistant Secretary's coming here this morning, because he has a great deal of work, and he asked me to tell you that he had a definite engagement with the Speaker of the House of Representatives and asked to be excused.

The program was slightly disarranged, as you know, yesterday afternoon, but we will continue here. Doctor Frost is not here. The next paper is "Cooperative certification procedure," a matter of considerable importance, and I will ask Mr. Emerson, State engineer of Pennsylvania, to speak. It is a matter in which we are very much interested.

COOPERATIVE CERTIFICATION PROCEDURE.

Mr. **Emerson.** Mr. chairman and gentlemen, it has been said by some that the amount of time devoted to the certification of water supply for interstate carriers is out of all proportion to the public health benefits derived from this work. A statement such as this should be carefully investigated and I would like the opportunity of offering a few points for your consideration in future discussions on this subject.

At the present time the railroads of our country are taking water supplies for use of passengers from some three thousand different points. Many of these are privately owned supplies, and if it were not for this certification there would be no public health supervision over such supplies. In numerous other instances—even though the supply is also furnished the public in municipalities—the laws of the State are such that the health authorities would be unable to issue orders for sanitary improvement and the power delegated through the cooperation of the Federal Public Health Service is about their only method of bringing these supplies to the desired standard.

To some of you this will mean little, but to others, and particularly the executives of the State where the majority of railroad watering points are privately owned or where the laws respecting purity of water supplies gives the State health organization but little power, this statement should mean a great deal.

Another feature now being given attention is the method of handling the water supply on trains. You, of course, appreciate the opportunities for contamination of a pure supply through careless or ignorant yard gangs and train crews. The undesirable conditions obtaining in the past are being rapidly corrected.

There is an impression from some quarters that this whole policy is in a nebulous state. This is hardly fair, either to the Public Health Service or to the engineers of the various States who are doing the field work. Last year a report was made to the Surgeon General by a committee of sanitary engineers, and this report was approved by your organization. Certain recommendations for modification of the certification method then being used were promptly adopted by the Surgeon General's office, and after almost a year's trial of this modified procedure I have within the past two days been informed by a number of the engineers here in conference that no further modifications of any moment are necessary at the present time, as the whole project is working so well.

The Public Health Service has asked for the opinion of the engineers as to the proposed modification of interstate quarantine regulations respecting the discharge of sewage in the vicinity of waterworks intakes. The engineers' conference has considered this carefully and has instructed me to report to you that, should the Public Health Service bring this clause up for amendment, the engineers favor it.

Another point which, I believe, should appeal to the State health executives is the mere fact that a report must be made to the Federal Government each year on the quality of water supply taken from the public mains by the railroad companies is a great incentive to your engineering force, for it constitutes a check on the extent of their water-control work throughout the State. It is conceivable that this examination for railroad purposes may also serve to bring to light dangerous conditions affecting the citizens of the municipality using this same water in their homes. In fact, I know that such has been the case. Is it, therefore, fair to charge against railroad certification all of the expense of the inspections and analyses? Should not a large percentage of this expense be charged against general inspection work?

Inasmuch as all but two States in the Union are now preparing these certificates for the Federal Government, and as most of the work for preparing them falls upon the engineering divisions of the various States, I believe you will welcome the assurance of the engineers' conference that the matter is of considerable importance to them and a procedure from which they derive benefit.

Doctor Cumming. Is there any discussion of Mr. Emerson's paper?

Doctor Welch. I would like to add my word of indorsement to the policy of municipal water control, brought about by this certification of water. There was one town in Alabama where we had not been able to induce the authorities to do anything toward the purification of the water. We had notified them several times that they must do certain things, but they only laughed at us. I asked permission of the Surgeon General to post the water. I notified the physicians of the two railroads going through that town that they must post in the railway station a notice that the water supply was unfit for human consumption. The plant was put in satisfactory condition in a short time.

The same condition obtained in another water supply in the northern part of the State, and as soon as the chamber of commerce found out that we would post the water supply they immediately got busy.

I should be very sorry, indeed, to lose this whip. The State Board of Health of Alabama will assume all responsibility, but we do want the privilege of demanding of the railroads that they post these water supplies when we order it.

We have not had any trouble with them so far.

Doctor **Cumming**. I will ask Doctor Beatty, of Utah, what the procedure is in his State.

Doctor **Beatty**. It has been a valuable agency in assisting us to improve the water supplies in various localities where our efforts had proved unavailing. In many instances communities are willing to tolerate contaminated water supplies as long as it can be done without the publicity which attends condemnation by the Federal authorities, and in the absence of power vested in the board of health to compel local authorities to provide water supplies which are reasonably pure, the Federal regulations have been of great service.

Doctor **Cumming**. May I suggest right here that all resolutions should be in by noon.

Is there any further discussion?

Doctor **Chesley**. I did not hear Mr. Emerson's paper, so he may have mentioned this point, but it seems to me that it might be possible through the service to get the National Board of Insurance Underwriters to take some action with relation to these emergency intakes for fire purposes, which so frequently are connected with the water-supply system. In Minnesota there is no trouble about it, but a uniform policy throughout the United States would be promoted by cooperation on the part of the National Board of Insurance Underwriters. The industrial insurance organization is in accord with public-health measures, and if this health phase of the fire-insurance organization could be brought to their attention it might aid the States in securing better and more prompt action with regard to the emergency intake.

Doctor **Cumming**. Doctor Frost is going to discuss the question of colon bacillus as an index of potability of water.

SIGNIFICANCE OF B. COLI IN WATER.

Doctor **Frost** (reading):

I feel that an apology is due an audience for undertaking to discuss a subject which has already been discussed so much as this, especially when it is certain that nothing new will be added. What is known with reference to the significance of *B. coli* in water in relation to health is the result of so many years of cumulative experience that what can be added by one or two years more of observation can have very little effect upon the sum total. Consequently, anything that may be said properly representing opinion to-day is in most respects identical with what would have been said some years ago, since, so far as I am aware, the last 10 years have seen only one important addition to our knowledge, materially affecting opinion on this subject.

Sanitarians are interested in water supplies primarily as potential vehicles of infection. What they wish to know regarding a water supply is its danger, in terms of the proportion of consumers who will contract infection as a result of drinking it. A knowledge of the water in terms of bacteriology is of secondary interest to them, solely as a means toward the end of forming an estimate of the water's danger.

The facts upon which an interpretation of a bacteriological or chemical examination of water is based are relatively few and simple and are so generally known that they are repeated here merely by way of review.

The first fact of importance is that the real element of danger in a water supply is the pathogenic microorganisms which it may contain.

The second essential fact to be recognized is that we can not at present demonstrate these dangerous pathogenic microorganisms in water by direct bacteriological processes, because they are present in such exceedingly small numbers as compared to other nonpathogenic organisms. To detect the typhoid bacillus, or other pathogenic bacteria, even in grossly polluted water, is a rare accident; and failure to detect them is by no means proof of their absence.

The third fact essential to the interpretation of any chemical or bacteriological examination of water is that all of the pathogenic microorganisms which constitute a real danger in water are essentially parasitic, having their natural habitat and breeding place in the bodies of man and other higher animals. Outside of this environment they tend naturally to rapid decrease or extermination, and therefore they are found in nature only in association with comparatively fresh excreta. Moreover, the pathogens of most serious importance are found only in human excreta, not in the excreta of lower animals.

Therefore, since we can not directly demonstrate the pathogenic organisms which may be present in water, our next most specific test for their presence is demonstration of the presence of excreta, especially human excreta.

For many years, with this general principle in mind, chemists and bacteriologists have been working toward specific tests for excreta. The problem is, however, a difficult one, for while the contamination resulting from a very small amount of fecal material added to pure water can readily be detected by either chemical or bacteriological tests, these tests do not prove that the contamination necessarily resulted from excreta. The most nearly specific chemical tests serve only to indicate broadly the kind and to measure roughly the amount of organic matter present. They do not differentiate between organic matter derived from sewage and that from less objectionable and entirely harmless sources. Similarly, the total numbers of bacteria as determined by gelatine or agar counts may be taken as indicating roughly the amount of organic matter present which is suitable for the sustenance of bacteria; but, although large numbers of bacteria are present in excreta, equally large numbers may be found in other organic wastes. Consequently the demonstration of excessive numbers of bacteria in water, taken by itself, does not indicate sewage contamination.

The most nearly specific test for excreta at present available is demonstration of the presence of the so-called "colon bacillus," since this organism is always present in large numbers in the excreta of human beings and higher animals. However, before this test can be considered absolutely specific, it is necessary to prove that the colon bacillus breeds naturally only in the bodies of man and other animals. It is upon this latter point that there has been and is considerable controversy—naturally, since such a proposition can be proven only by exclusion, and even an approximation to proof requires an enormous mass of negative experience.

Notwithstanding the impossibility of absolute proof, a large majority of sanitarians in this country familiar with the bacteriological examination of water would have stated quite positively 10 years ago that the presence of colon bacilli as then defined was definite and specific evidence of fecal contamination. They would have based this opinion upon their general experience that these organisms were ordinarily found only in waters which were obviously subject to fecal contamination, and that the numbers of colon bacilli found were roughly proportional to the exposure of the water to fecal contamination as shown by sanitary survey.

On the other hand, there was a very considerable and highly authoritative minority, especially strong in England and Germany, who held the opposite view—that the colon bacillus, though always present in feces, was widely distributed in nature as a saprophyte, and that its presence did not necessarily indicate the presence of excreta. Their reason for this view was chiefly that a large number of studies had shown the presence of colon bacilli on grain, grasses, and fruit, and in soil where the probability of recent fecal contamination seemed extremely remote.

In 1913 and 1914 Rogers and Clark, of the United States Department of Agriculture, began what proved to be a fundamental piece of research. Using highly refined bacteriological and chemical methods, they demonstrated conclusively that the so-called *B. coli* group, which had previously been considered one group of bacteria, really comprised two separate and distinct groups, one representing "true *B. coli*" and the other a similar but distinct "aerogenes group." These two groups, which gave more or less identical reactions by tests previously applied, were distinctly differentiated by different ratios of hydrogen to carbon dioxide in the gas formed and by different hydrogen ion concentrations established in special media under standardized conditions. The differentiation as first made by Rogers and Clark required rather elaborate apparatus and technique, beyond the reach of most water bacteriologists; but subsequently, as a result of work by Doctor Clark and others, the technique was greatly simplified, so that the differentiation can now be made by very simple tests, requiring no special apparatus.

Applying these tests to large numbers of cultures derived from different sources, Rogers and Clark found that the colon bacilli found in feces, whether human or animal, belonged almost exclusively to one group, which they called the "fecal group," while the colonlike organisms found on grain belonged usually to another group, which they called the "nonfecal" or "grain" type. Their work is still relatively new, but already it has been confirmed by quite a number of independent observers, and, so far as I am aware, all subsequent work tends to establish the original conclusions arrived at by Rogers and Clark—that the "fecal type," or true *B. coli*, is predominant in fresh feces and in material exposed to fecal contamination, while the colonlike organisms found on grains and in unpolluted soil almost invariably prove to belong to the "aerogenes group."

As to the significance of this, a good many sanitarians appear to have the impression that it renders the ordinary test for *B. coli* less significant than previously. While this may be a natural viewpoint, it is not justified. It is true that a positive test for *B. coli*, made according to present standard methods, may indicate the presence not of true *B. coli* but of the nonfecal aerogenes type. But this has always been true, though not previously recognized; and the probability that a positive standard *B. coli* test in water means fecal contamination is just the same now as it was 10 years ago. Moreover, in cases of doubt or special importance it is now possible to carry the test further and determine whether the organism is true *B. coli* or aerogenes. Also, this recent work appears to offer a satisfactory explanation of the finding of so-called *B. coli* in the past in situations where their presence could not be satisfactorily accounted for as due to fecal contamination. Presumably these organisms were of the aerogenes type, not true *B. coli*.

The American Public Health Association has not yet made it obligatory in their Standard Methods to differentiate *B. coli* from aerogenes, but they describe the technique, so that any reasonably well-trained bacteriologist can make the differentiation. In the absence of such differentiation a positive test should be interpreted as heretofore; that is, as constituting strong presumptive evidence of fecal contamination. Admitting that this is not positive proof, the benefit of the doubt should be given to the public and the contamination should be considered as of fecal origin unless evidence is brought forward to the contrary.

So far the discussion has referred only to demonstrating the presence of contamination with excreta; but even granting that the presence of excreta is demonstrated and the extent of the contamination measured, this still is not equivalent to measuring the danger of the water in terms of the probability that it will cause infection. For this several further steps are necessary.

First, it is necessary to differentiate between excreta from lower animals and that from human beings. As this can not be done by means of chemical or bacteriological tests, it requires a survey of the sources of contamination to which the water is exposed. This may afford more or less definite information. For example, *B. coli* is of much more dangerous significance in a well obviously contaminated from near-by privies than one not subjected to contamination from privies but located near a heap of stable manure.

However, even the demonstration that water is contaminated with human excreta does not necessarily indicate that it is immediately dangerous and falls far short of measuring its danger. A well or spring grossly contaminated from a privy and used by a small number of people may not be actually dangerous merely because none of the people contributing to its contamination is infected with any pathogenic organisms. Such a well, though very offensively polluted, may not cause any infection within a generation. On the other hand, it is quite certain that a river such as the Ohio, which constantly receives sewage from several millions of people, always contains typhoid bacilli and other pathogenic intestinal bacteria. This is necessarily so because among the millions of people whose excreta reach the stream there are always a very considerable number harboring pathogenic bacteria, either as active cases or as carriers. The only question as to such water is not whether or not it is dangerously contaminated but to what extent.

But even when it is known that a water contains typhoid bacilli or other pathogenic bacteria, this still does not constitute an active measure of its danger. Even if we knew the exact number of typhoid bacilli per thousand liters of water, we still would not know what proportion of the people drinking this water would become infected, because we know practically nothing as yet regarding the dosage necessary to cause natural infection. Nor have we more than the vaguest ideas as to the relative danger of waters containing different numbers of pathogenic bacteria. For example, if a water containing 10 typhoid bacilli in a certain volume will cause infection in 10 per cent of the people who drink it, it by no means follows that a water containing one typhoid bacillus in the same volume of water will cause 1 per cent of infections. Conceivably it might still cause the same proportion of infections as the more highly contaminated water, or it might cause none. We simply do not know the effect of varying dosage of infective organisms.

The nearest approach that has been made to the exact knowledge of the danger of water supplies, in terms of the number of cases of infectious disease which they will cause, has been made not by bacteriological studies but by epidemiological observations. For instance, our estimate of the danger of raw water from the Ohio River is based not on its bacteriological examination but on past experience in cities where this water has been used; an experience which has shown that 1 per cent or more of the consumers develop typhoid fever each year, whereas the same cities when using more or less adequately purified water supplies have not suffered much more than one-tenth such a typhoid incidence rate.

I have dwelt upon the difficulties and indirection of estimating the danger of water supplies, not with a view to casting doubt upon the value of bacteriological examination but merely to emphasize the point that the sanitarian who attempts to estimate the quality of a water supply must take into consideration not only the bacteriological evidence of pollution but also the character of the sources from which the pollution presumably comes.

In extreme cases an interpretation may be very simple. For instance, a water which consistently gives negative *B. coli* tests and very low bacterial counts may be pronounced safe so far as infection is concerned without knowing anything more about its origin. Equally, the water from a stream known to receive the sewage of a city a short distance upstream may be condemned as unsafe without the formality of a bacteriological examination. It is the intermediate cases which are difficult; those in which bacteriological examination shows moderate contamination and a sanitary survey reveals exposure to possibly though not certainly dangerous contamination. As to such cases there is always room for perfectly legitimate differences of opinion, which can be proven only when epidemiological evidence shows that the water is responsible for infection or that it is causing none. It was circumstantial epidemiological evidence which first proved the agency of water supplies in spreading infection, and it is evidence of the same kind, rather than direct bacteriological evidence, which best serves to-day to establish and measure the danger of a water supply.

Doctor Cumming. Is there any discussion?

Doctor Garrison. I would like to ask a question, to throw what light I can on the question of domestic animals that have colon bacilli. This matter came up at Hot Springs, where the Government and the State are involved. The limited literature at my disposal did not disclose very much on it. I would like to have him tell us about that if he can.

Doctor Chesley. I will ask Doctor Park to answer that. I believe all the higher or lower animals, all animals and fowls, have colon bacilli very abundantly in the feces.

Doctor Garrison. That was my general impression, but the text-books down there were to the contrary.

Doctor Park. There was rather an extraordinary condition in New York. We found colon bacilli increased very rapidly in the reservoir after being purified. Suspicion was directed to a flock of gulls that came over. This year when they came over again we found colon bacilli. I would say that apparently nearly all wild animals and fishes produce it.

Doctor Stiles. In connection with the question of drinking feces through the drinking water it is interesting to note that we have entirely independent tests which go to prove definitely that we all eat human feces. An advantage of one of the tests which we have is that we can tell definitely that the fecal material we have consumed comes from human beings. In entering almost any locality we can prove microscopically that anywhere from 10 to 90 per cent of the population have actually swallowed human excreta. There is no doubt but that 20 per cent of us would give a positive test, while if we go out to the people in the rural districts and among the cotton-mill population we can run that up to 70 or 80 or 90 or 100 per cent. According to the average population in Washington it would run between 10 and 20 per cent, so that we all eat human excreta, quite independent of any test we have from the bacteriological view in regard to colon bacilli. The other test which I have mentioned has great advantage, in that we can prove it is definitely human excreta.

Doctor CUMMING. Doctor Park needs no introduction to any health officer in the country. He will now talk to you.

TOXIN-ANTITOXIN, AND THE SCHICK REACTION.

Doctor PARK. It is difficult to decide just what aspects of the Schick test and the toxin-antitoxin injections to take up before a body of trained health workers. If I treat in too general a way any portions that you wish to hear more about, I hope you will ask questions in the discussion.

In the February monthly bulletin issued by the New York City health department I have summarized all the experimental and practical work done on the Schick test and the production of active immunity. Copies will gladly be sent to any who request them.

The Schick reaction: This is a very dependable test if the correct amount of toxin is given intracutaneously. If the injection is faulty either in the amount given or in the method, it gives misleading results and is not a true Schick test. If too much toxin is administered, too many of those injected react; if too little is given, we obtain too few reactions and have a false feeling of security. If the toxin is not injected entirely intracutaneously, it is not retained in the skin and so does not produce its full local effect. The first essential, therefore, is that the laboratory should test the toxin and send it out in just the right amount. Until very recently the laboratories have frequently erred by supplying either an excess or a deficiency in the amount of toxin, and thus getting too large or too small a proportion of positive Schick reactions. The deficiency has been due not to the fact that too little toxin was put in the container, but because we did not realize that the glass of our containers, whether bottles or tubes, is often unsuitable and affects the toxin badly. Within even a few weeks improper glass will cause a great deterioration in the toxin.

Some time ago, because of certain results reported to us, Doctor Zingher asked the manufacturers of biological products to send us a number of their outfits. In over 30 per cent of them we found that the toxin was deficient in amount. Last summer the manufacturer who had always supplied us with suitable glass felt aggrieved at the way the contract had been awarded and sent us an inferior article. As we had tested the toxin put up in his glass tubes for many years and had not found any deterioration, we omitted to test this lot. Soon we got a report that our toxin, used in comparison with that of another biological plant, gave less reaction. Samples of both toxins were sent to us, and we found that ours had 40 per cent and the other had 180 per cent of the required amount. Just recently we had a portion of a bottle of toxin sent us which had been prepared by a private manufacturer and had been held for six months, with the comment that 100 children had been Schick tested without a positive reaction. We sent them some of ours, and on the retest 30 per cent of these same children reacted positively. If any health officer tests 50 or more children with toxin and no characteristic reaction develops, he can be sure that the toxin is unsuitable and should be discarded. These incidents are merely samples of many in which I know the results of the tests were faulty. We can sum up by saying that a suitable Schick test is extremely reliable, but that many so-called Schick tests, because of faulty toxin or faulty technique, are misleading.

What proofs have we that a negative Schick test does give us assurance that sufficient antitoxin is present to supply protection against diphtheria? You realize that Schick tried to select for the intracutaneous test a definite amount of toxin which, if it gave a reaction, showed the case was not immune because of antitoxin; if no reaction developed that the case was immune. To find an amount which would make such an absolute separation of cases would be too much to expect. Antitoxin which would just prevent a diphtheria infection under ordinary conditions of health could hardly do so if the case were complicated as by measles or tonsillitis. If the minimum amount to prevent a Schick reaction did not always prevent a slight local infection, would there be enough antitoxin to prevent a serious development of diphtheria? I have studied this matter carefully and I am perfectly sure that there are cases occasionally with slight tonsillar exudate and positive cultures that have the negative Schick test. For instance, last week at the institution of St. Dominicks, where there are 1,500 children and where we have been giving the toxin-antitoxin at intervals for seven years, it was recently reported that they had two children with suspected diphtheria who had given negative Schick tests last January.

One of the children had developed a tonsillar deposit and a temperature of 103. At the end of the second day a culture was made. On the third day, because of a positive report on the culture, antitoxin was given, but the child had already improved.

The other child showed a slight sore throat but no exudate. The culture was also positive. Did these two children have diphtheria?

In one case recovery began before antitoxin was administered. In the other no antitoxin was given and no exudate developed.

You may remember a report of mine in regard to an institution in which all the children had given some months before the negative Schick test, yet seven children developed tonsillitis with patches within a week's time, and all were shown to have diphtheria bacilli. All the children but the last one received antitoxin, and this one, like the others, recovered promptly. If I had not withheld the antitoxin from the last case it would have been thought that antitoxin had cured the others.

In a hundred other little children living in different wards in this institution no suspected cases developed, yet when we made cultures we found the extraordinary condition that over 50 per cent of these children carried virulent diphtheria bacilli in their throats. My interpretation of these cases is that it is possible under unusual conditions, such as an infectious tonsillitis, together with a diphtheria-carrier condition, to develop a slight diphtheria even in cases having just enough antitoxin to give the negative Schick test, but I believe these cases will never be severe and will recover without additional antitoxin.

Before taking up active immunization let us consider the need of additional measures to combat diphtheria. We have noticed in New York, Pennsylvania, Massachusetts, Connecticut, and other places that there has been only a moderate decrease in the number of cases through the use of isolation guided by cultures, and the use of immunizing doses of antitoxin has been very much greater, for the deaths have been reduced to one-fifth their previous number.

It is rather interesting that during the last nine years the diphtheria mortality in New York State, outside of the city, has risen from about 11 per 100,000 to 18 per 100,000. In New York City it rose from 19 per 100,000 in 1916 to 22 per 100,000 in 1919. Up to 1920 there were in New York City about 15,000 cases and 1,200 deaths a year. These facts make us appreciate that we have not yet conquered diphtheria. The only additional measure that seemed immediately available was the testing out of the value of active immunization with diphtheria toxin modified by antitoxin. With the Schick test it became very easy to test whether toxin-antitoxin injections in children would give antitoxic immunity; and if it developed, to test its duration. Babes away back in 1895 showed it developed in guinea pigs and that it lasted at least for some months. Some years later Theobald Smith showed it lasted about two years. Could we expect it to last longer in a human being than in guinea pigs? We could at least hope that it would, because there is some tendency in a human being to develop and maintain natural immunity. Whether this natural development of antitoxin is due to the person becoming a carrier or is an inherent condition we do not know, but the fact gave us the hope that if antitoxic immunity were once developed it might be a permanent acquisition.

The toxin-antitoxin vaccine: Why did we choose the mixture we are using? We knew from animal experimentation on horses and guinea pigs that a tremendous amount of slightly overneutralized toxin could be safely injected and give more antitoxic response than a safe dose of straight toxin. We did not know how much toxin to use in children, but we started off to use in 1 cc. of mixture three L plus doses of toxin neutralized to such an extent that 5 cc. of the mixture would produce paralysis in a guinea pig. This mixture was effective, but because of the large amount of bacillus protein in it it caused in some severe reactions. We also tried giving five L plus doses of neutralized toxin. This gave us no better results, and so I determined to try one-half of an L plus dose and also one-tenth of an L plus dose of toxin. The children receiving the one-tenth L plus as a dose have almost no annoyance from the injections. In the only school in which we have made retests the results are as good as with those receiving the three L plus doses.

The immunizing results: At my request Doctor Zingher selected in 1915 a number of institutions where the children remained for some years. He Schick tested the children, and he and Doctor Schroder have retested them year by year. It has been found that in nearly all cases a child becoming immune remains so for at least six and one-half years. Very few relapses have occurred, and the children who relapsed became negative and remained so when reinjected with toxin-antitoxin. Possibly we are a little too optimistic in our estimate of the duration of the immunity, because in injecting the children every one or two years with toxin of the Shick test there may be a little stimulus to the development of antitoxin. To eliminate this factor we shall not make retests in certain institutions and schools until after the lapse of a number of years.

In New York we have had absolutely no serious consequences from the administration of the toxin-antitoxin. We have had, of course, the usual proportion of swollen arms. Fortunately, little children under 3 years seldom develop annoying reactions except slight local swellings and temperatures. The older children have in about 10 per cent sore arms for two or three days, with or without some rise in temperature. When we first started the injections we prepared our own toxin from bouillon made from meat which was allowed to ferment through the multiplication of the germs clinging to it. In this first fermentation certain slightly toxic products were occasionally formed which were not destroyed by the subsequent heating. These products created a disturbance in certain individuals. Indeed, we had four cases in which there were definite toxic effects; these children were prostrated for a few hours. Since then we have used nothing but the soluble products of fresh sterilized meat for the nutrient medium. To this has been added the colon bacillus to ferment the sugar, and then the diphtheria bacillus to provide the toxin, so there can be no proteins in the toxin broth except from the diphtheria and colon bacilli and from the meat itself. We are now testing out a product which has only one-thirtieth of the bacillus protein that the present preparation contains. If this new mixture answers as well as our present one, we will greatly lessen these annoying reactions, and so remove the only real objection to the injections.

Supposed illness following the injections: If hundreds of thousands of children are injected, there will surely develop in some illness which is a mere coincidence and not due to the injections. As an illustration I will mention something that happened some years ago. I asked a physician to go to Staten Island to inject an infant with toxin-antitoxin. On account of a sudden storm he deferred his trip until the next day, and then found the child had died of convulsions during the previous night. If he had injected the child at the time set, it would have been thought that the vaccine had killed it. Among the 60,000 children that have received the injections through us there is only one in which death has occurred within a period of a few weeks. This child died of meningitis. The only possible connection would be that the toxin-antitoxin lowered the child's resistance and so made infection possible.

The value of immunization of school children: The attempt to immunize the school child is worth while, both because of the actual protection given and because it paves the way to reach in the same families children of pre-school age, who are really the ones most in need of protection. We believed that if every parent of a school child should receive a letter from the department of health urging immunization against diphtheria, it would make an immense impression on the people of the city of New York and it would help to persuade the parents to have the younger children receive the injections either from the health officials or from their private physicians.

For these two reasons we have devoted ourselves during the past two years chiefly to the schools. By June almost every public-school child in New York will have received a circular of information to take home; nearly 300,000 of them will have been Schick tested, and, if necessary, given treatment. With the closing of the schools we expect to make a drive to vaccinate the children who are too young to go to school.

Certificates: These are given in two forms. The first simply states that the injections have been received, the other that a retest has established immunity. One should never give a certificate of successful immunization after merely giving the injections, because we know that anywhere from 10 to 30 per cent of the nonimmunes will not be fully protected from diphtheria by one series of injections. Such a certificate may give a false sense of security to the parents. We therefore issue immunization certificates only after a negative Schick reaction at the retest. Retests are made four to six months after the completion of the injections.

The results observed among the test children: We have indexed 90,000 children who have been Schick tested by the physicians working under Dr. M. C. Shroder and Dr. A. Zingher. About 80,000 of these had an originally negative Schick test or the retests after the injections were negative. About 10,000 of those who were originally positive and who received two or three injections have not been retested or on retest were found to be positive.

The following table gives our findings:

TABLE 1.—*Number of suspected cases of diphtheria developing in 90,000 untreated school children and in 90,000 who had been Schick tested and when positive given two or three injections of toxin-antitoxin.*

Number of children.	Result of Schick test.	Result of retest, if retested.		Number of reported cases of suspected diphtheria.
60,000	Originally negative	Not retested	80,000	4
20,000	Originally positive	Became negative		
8,200	Positive	Not retested		4
1,800	.....do	Remained positive		4
90,000	Tested and when necessary injected			12
	Neither tested nor injected, controls			54

Summary: Among the 90,000 untreated school children there developed 54 cases of probable diphtheria during the past four winter months. Among the 90,000 school children of the same ages who were Schick tested last spring and, when positive, given two or three injections only 12 developed the disease.

Of the 90,000 tested children, about 80,000 were either originally negative or on retest after the injections found to be negative to the Schick test. Only four of these 80,000 developed suspected diphtheria. This demonstrates that a negative Schick test indicates an almost complete immunity to diphtheria.

Among the 8,200 who were originally Schick positive and were not retested after the injections, 4 cases developed. These 8,200 were, as a rule, among the latest to receive the injections. The 1,800 who in spite of the injections developed insufficient antitoxin to prevent a moderately positive Schick test showed the highest incidence of the disease. This result emphasizes the necessity of a Schick test several months after the injections. Those who still give the positive reaction should receive a second series of injections. You may not realize that we have as a protection from diphtheria both antitoxic and bactericidal immunity. There is no practical way to test the bactericidal immunity.

Doctor CUMMING. Before beginning the discussion we can take up the allied papers—" The effect of distribution by the official agencies of biologic products on child morbidity and mortality." Doctor Hayne will talk about this.

DISTRIBUTION BY OFFICIAL AGENCIES OF BIOLOGIC PRODUCTS ON CHILD MORBIDITY AND MORTALITY.

Doctor HAYNE. This is an unexpected honor, but I always have an impromptu speech with me. I am not a scientist. I am a plain, blunt man who loves my fellow men and women and children.

South Carolina has the unique position, which will be disputed by the majority of the States, of actually distributing diphtheria antitoxin free to its citizens. A great many States claim to do this, but do not do it. We distribute it free to every citizen in South Carolina, and there are no strings to it. Whether this does good or whether it does harm we are prepared to prove by mortality statistics. Morbidity statistics are about as inaccurate in South Carolina as they are in Maryland or Massachusetts. Therefore we lay no stress upon morbidity statistics, but our mortality statistics are about 90 per cent correct. We believe that because they have been investigated and accepted by the Census Bureau, which is a department of the Federal Government, and therefore can not err.

We have been following our statistics in South Carolina since 1915, when we entered into the registration area, and that is only a period of seven years, and we are sorry to say that our death rate in diphtheria is going up rather than going down.

We started the free distribution of diphtheria antitoxin in 1908, so that we had been distributing it seven years before we got our first reliable mortality report. I believe that in about 1890 or 1900 the mortality statistics for the United States showed that there were 43 per 1,000 deaths from diphtheria in the United States, and the average mortality in 1918 was about 18 per 100,000 of population. The average mortality in South Carolina is about 6 per 1,000. This is the lowest mortality of any State in registration area except Vermont, Montana, Washington, and Colorado, and, of course, in Montana, Washington, and Colorado, especially Montana, the distances are so great between carriers and between individuals that there may be some reason for that low mortality in Montana outside of the climate.

In Vermont we can only attribute it to the fact that Vermont, like South Carolina, is a rural State to a great extent, and it has an excellent State health officer in charge of its affairs.

Joking aside, we feel our method of distribution of diphtheria antitoxin is ideal.

I would like to read you a clause of the contract that we have with a biological firm for the distribution of antitoxin. We used to manufacture it, but after having killed four children in one summer—or at least we were so accused—and having a $25,000 verdict brought against the State, we feel a sort of delicacy in manufacturing and we prefer to let some biological firm take the responsibility. In other words, we are passing the buck. I will read you this clause that I referred to.

(Clause referred to read.)

I read that to show what we are doing in that respect. The antitoxin is put in every hamlet in South Carolina. South Carolina is 85 per cent rural, and there are no cities except Charleston. The rest are really overgrown villages. At no point in South Carolina is a depot more than 5 miles from a doctor. A doctor can get any amount of diphtheria antitoxin free, from 200,000 units to the proper amount, which, if the case is recognized in time, is about 5,000 units, or not over 10,000. Of course, as I say, I am not a scientist, but the amount they get usually cures them.

We have found, of course, that there is a large amount of diphtheria antitoxin administered to children who do not have diphtheria, but we have not found any bad results occurring in the children or any deaths on account of giving diphtheria antitoxin, whereas prior to the administration of diphtheria antitoxin there were very bad results from those who did not get diphtheria antitoxin where they had diphtheria.

I believe there is no single measure that has done as much toward reducing the death rate amongst children with diphtheria as the fact that a doctor can get it free, that he does not have to make out a pauper's certificate to get it, that it is easier for him to give it than not to give it, and for that reason I think our method is the best that I know of.

It costs the State—and we are dealing with budgets nowadays, so you are interested—it costs South Carolina about $13,000 to give this. That is the maximum amount it ever cost. We have a population of 1,700,000 people, black and white, and it is not a prohibitive cost to give it free.

Take your big States and proportion it to that amount, say $1,000 or $750 per 100,000 of population, and you get the price. I would like to briefly tell you what we are doing with the Schick test and toxin-antitoxin.

I may not have completely understood Doctor Park. My impression was they did the Schick test before giving the toxin-antitoxin. We give the toxin-antitoxin to every school child, regardless of whether they are positive or negative. That is expensive, but we are doing it as an experiment in one county—the county of Charleston, outside the city of Charleston. We have immunized and card-indexed 3,000 children in the county. We propose to find out in a year or two whether those children have diphtheria, how many have it, and in that way we will be able to report something worth while in regard to the immunization of children with toxin-antitoxin. We give the typhoid and paratyphoid free, and it gives a tremendous reaction; therefore the slight reaction from the toxin-antitoxin is appreciated by the people. We do not distribute it free in the State unless we are convinced that the physician who obtains the toxin-antitoxin is capable of administering it, and whenever we are in doubt we have them come to the laboratory and show them how to administer it.

Doctor Cumming. The next topic is "State-wide programs for the application of the Schick test and toxin-antitoxin immunization." Doctor Nichols was here and had to leave. We will proceed with the next question, which is "Standardizing technique," by Doctor McCoy, director of the Hygienic Laboratory.

STANDARDIZING TECHNIQUE.

Doctor McCoy. It is traditional with men who work on the same line with Doctor Park that after he has spoken on diphtheria nothing remains to be said. Doctor Park, however, refrained from taking up the matter of standardization of the agents under discussion, and it is on this point that I will speak briefly.

Introductory to this, I should like to say it appears that in the Schick test we have about the only truly logical and scientific prophylactic inoculation in use, because by means of the Schick test we find out in advance just what particular persons need immunization and then proceed to immunize them with the toxin-antitoxin mixture. In the case of typhoid, smallpox, and other prophylactic vaccinations we immunize everybody and doubtless immunize many who have a natural immunity to the disease in question.

Standardization of the Schick test has recently been ruled by the Surgeon General's office to come under the provisions of the law of July 1, 1902, which requires that a license shall be obtained by the manufacturer before selling the product in interstate traffic. The details of our efforts at standardization would not be of special interest to you, but you will be interested to know that the manufacturers are required to send samples of each batch to the Hygienic Laboratory for testing and approval before they distribute it. The same thing applies to the standardization of the toxin-antitoxin mixture. Before we undertook this work there had been a considerable variation in the strength of the preparation, and there had been one very disastrous accident in the Southwest, where a mixture was sent out so highly toxic that it resulted in a number of fatalities. The present means of control is believed to insure two things; first, an efficient preparation and the distribution of a product having the proper degree of toxicity; and, second, no dangerously toxic preparation will be distributed.

In connection with Doctor Haynes's discussion, I think it is proper to state that no one need be discouraged with respect to the expense involved in the free distribution of antitoxins. There has been such active competition recently between the manufacturers that the price at which antitoxin can be supplied is amazingly low. I am acquainted with one State contract recently in which the price was something like 20 cents for the 1,000-unit package, 48 cents for the 5,000-unit package, and 98 cents for the 10,000-unit package.

Doctor CUMMING. Is there any discussion of these papers?

Doctor DILLON. These papers which we have just listened to have been very valuable ones. There are one or two statements, made or implied, by Doctor Park with which we have to disagree, and that was the statement, if I understood him correctly, with reference to the question of diagnosis of the mild case of sore throat in which there was a slight formation of a false membrane, and a positive laboratory finding of diphtheria bacillus. It seems to me there should be no question as to this being diagnosed as a case of diphtheria. I believe for the protection of the public a person with diphtheria should be isolated and quarantined; likewise, a person who is a carrier of what has proved to be a virulent strain of diphtheria bacilli. In my opinion, the public has a right to demand protection by their isolation so long as they remain a carrier. During the past six weeks my attention has been invited to a death in which the cause of death was given as spasmodic croup. We refuse to accept spasmodic croup as a cause of death, but have preferred to treat it as a probable case of diphtheria and prohibited the holding of a public funeral. The attending physician assured me that this child, who was 3½ years of age, and who had been sick three days, had no evidence of a sore throat, but a post-mortem which was held disclosed a larynx whose mucus membrane was covered with the diphtheritic exudate. Smears made from this membrane and examined in the laboratory confirmed the diagnosis by the presence of Klebs-Loeffler bacillus. An interesting thing in this connection is the fact that this body had been embalmed 18 hours prior to the holding of the post-mortem. Our laboratory made every effort possible to obtain a growth from the specimen of the diphtheria membrane, but in every instance was unsuccessful. In my opinion, this child died not as a result of the toxins of diphtheria but because of the mechanical obstructions of the larynx from the diphtheritic membrane. Yet the attending physician assures me that it had no clinical evidence of the sore throat. I would like to ask Doctor Park if this is not a diphtheria death, what is it?

Doctor RAWLINGS. I would like to ask Doctor Park the following questions: How many of his series of 90,000 had three separate injections of toxin-antitoxin; and, does glassware affect toxin-antitoxin as well as the toxin used in the Schick test?

I wish to ask Doctor McCoy if the Hygienic Laboratory pays any attention to the quality of the glassware used for these biological products?

In Illinois we distribute antitoxin to rich and poor alike. We have in Chicago and other sections of the State approximately 400 places where diphtheria antitoxin and other toxins and sera may be obtained. In spite of a very favorable contract these products cost the State of Illinois over $40,000 a year.

We have not been able to obtain as good results as we had hoped for from the general use of free antitoxin in the reduction of our mortality from diphtheria, either in Chicago or in the rural districts. I wish we could report as favorable results as those given by Doctor Hayne. We believe it is a worth-while procedure in aiding in reducing the death rate, but I think health officers must concede that our best hope in rendering our communities immune lies not in the diphtheria antitoxin but in the general use of toxin-antitoxin. This is especially true because of the big carrier problem. Many of these carriers have virulent diphtheria germs constantly in their throats and we must make immune those who are in contact with these carriers.

Doctor CUMMING. Is there any further discussion?

Doctor MITCHENER. From the comments voiced this morning there has seemingly been a greater effort made to immunize children of school age with toxin-antitoxin than there has been to immunize those between 6 months and 6 years of age. In North Carolina we have not put forth as much effort to give toxin-antitoxin to children of school age as in the six-months-to-six-years group, because in this group we get a larger percentage of our cases and a higher death rate.

Early in the spring of 1921 it was decided to offer toxin-antitoxin in our county-wide campaigns which, as most of you know, we have been conducting in North Carolina for several years. We advised the older children and the adults to take typhoid vaccine and the younger ones to take toxin-antitoxin. The response was exceedingly gratifying, not only as to the large number of people who received three treatments of typhoid vaccine (70,000, or about 16½ per cent of the population of the area worked) but also a large number immunized against diphtheria, 10,000 having taken three doses of toxin-antitoxin. In Green County, which has a population of about 16,000 people. 4,529 were given the typhoid vaccine and 1,238 took toxin-antitoxin.

I might state that we have ignored the Schick test entirely because of—

(1) The trouble—since we can immunize with about as little work as one meets in giving and observing the test.

(2) Lack of experience on the part of the men in interpreting the reaction.

The large number immunized in these campaigns is attributed to the fact that the treatments were administered by local physicians, from one to eight participating in each county.

Doctor CUMMING. Is there any further discussion? Doctor Park, would you be good enough to answer the questions?

Doctor PARK. Let us consider first the question as to the propriety of the free distribution of unlimited amounts of antitoxin by State and city departments of health.

An example will help to explain my position. A physician recently called up the laboratory and asked for 250,000 units of tetanus antitoxin. The physician in charge explained to him that 100,000 units would cover the requirements of any case however severe. He answered, "I am asking for antitoxin; not for advice." So he was told, "You can have 100,000 units free, but if you want any more you will have to pay for it." He replied he did not wish to pay for any, so he would take the 100,000 units offered.

I think that a health department should distribute free any reasonable amount of a biological product, but beyond that it should make a charge. No one up to this time has paid a cent for anything beyond the amount we thought suitable. The conviction among physicians, therefore, is not very strong for these tremendous doses. When physicians receive serums free they are apt to think in excessive amounts. They do not seem to realize that 10,000 units of diphtheria antitoxin are one hundred times as much as would be required to neutralize the greatest amount of toxin that any case ever had. We give as much as 10,000 units so as to get sufficient antitoxin quickly through the capillary walls to the diseased tissue, just as we pour enormous amounts of water on a burning building, more than would be required, if it could all reach and remain in contact with the actual materials on fire.

The necessity of the use of the Schick test before the toxin-antitoxin injection depends on the actual conditions as to the age of the children and the help available. Under 3 years of age I think very few of us would advise a Schick test, except in family practice or in institutions where one is in contact with the children, and may repeat the test from time to time. The immunity derived from the mother is usually lost in the first year, but some children hold it for two or three years; therefore, a negative Schick test for this age is not a positive sign of permanent active immunity. After three years the Schick test, besides eliminating those who are negative from those to be injected, has the great value of proving in these latter whether or not there is a lasting immunity. After 6 years of age only about one-half of the children require toxin-antitoxin, and it is therefore usually wise to give the test. Yet because we do not need the same expert supervision for the injections as for the test and because by omitting it we save time, it may be better even after the age of 6 to give toxin-antitoxin without the Schick test.

If the toxin-antitoxin is given to all, there is the advantage, of course, of getting a little credit for immunizing those that were already immune.

Before I forget it I want to speak in regard to the enormous value of Doctor McCoy's supervision of the biological products. His trained staff of workers at the central laboratory checks the results obtained by all of us in our laboratories and so gives to us and the public an added safeguard. One serious accident that happened some time ago would never have occurred if the manufacturer had sent his products to Doctor McCoy for control tests. By keeping in touch with all, Doctor McCoy is able to make regulations of great value which almost prevent the possibility of mislabeling or accident.

I think that I was misunderstood as to the question of the practical application of the cultural test to treatment and diagnosis. It is strange for me to defend my present ideas since I believe I introduced the culture test. When cultures were proposed in New York City in 1893, I remember I thought we could gradually eliminate diphtheria by separating those who were infected with the bacilli from those who were not. This hope was not fulfilled because the healthy carrier was found to be so widespread that the isolation of cases had little effect on the general morbidity rate.

The culture shows simply whether a diphtherialike bacillus is present or not and does not make a diagnosis. Except where characteristic membrane is present, the clinical signs may also fail. Doctor Thompson showed that about 10 per cent of the cases of laryngeal stenosis received at the Willard Parker Hospital were not infected with diphtheria bacilli and had no exudate or pseudo membrane in the larynx. This catarrhal inflammation causing stenosis is apt to appear before a child develops a measles rash or during an attack of so-called influenza.

Some time ago the director of the bureau of hospitals of the department of health had a bad patch on his throat and he thought it to be diphtheria. Antitoxin was given immediately and a culture was made. The culture turned out to be negative. If bacilli had been present, we would have called it undoubted diphtheria, while in fact the bacilli would probably have been inactive.

I remember when we first applied the culture test in the diphtheria wards in New York City half of the patients did not have the diphtheria bacilli in the exudate. These patients had been sent to the hospital as a safety measure, because they were suspected of having diphtheria. No one would approve of holding back antitoxin if he suspected diphtheria until the culture results were obtained.

A lot of children get tonsillitis in the wintertime, and some are carriers of diphtheria bacilli which may or may not cause diphtheria. When we make cultures and find diphtherialike bacilli we do not know whether the bacilli are taking an active part. Indeed, from the smears alone we do not even know that these organisms are virulent. From the standpoint of prevention we assume their virulence and declare that the cases are a danger to others and treat them as cases of mild diphtheria.

Last year we limited the children in many schools to two injections of toxin-antitoxin with the idea that it was more practical to give all positively reacting cases only two injections; then, on repeating the Schick test in three months, to reinject the moderate percentage of those who reacted positively, rather than to give all the children the three injections. We found, however, that there was considerable difficulty in getting the Schick retests, and so we have finally settled on giving three injections to all who require protection.

It is interesting to note that while we have been attacking diphtheria from a new angle the mortality has dropped in New York City much below the lowest recorded rate. This year the mortality so far has been the same as last year, but the number of cases has been much less. We consider the showing this year to be very encouraging, as we have had a great increase in measles. We believe this infection caused many cases of diphtheria carriers to develop the diphtheria and also caused some cases of fatal croup that were not diphtheria to be counted as such. We feel so hopeful that we are planning a campaign to immunize as far as possible every child in New York City.

Doctor CUMMING. Doctor Rawlings, what is the population of your State?

Doctor RAWLINGS. A little over 7,000,000.

Doctor CUMMING. Doctor McCoy, will you answer Doctor Rawlings's question?

Doctor McCOY. We took into consideration the question of glassware.

Doctor CUMMING. Is there any further discussion?

Doctor CHESLEY. The very low prevalence of diphtheria fatalities in Washington has been a source of amazement to us. I wonder if the Schick test has given any information to explain this low morbidity.

Doctor McCORMACK. The Schick test there did show a very large percentage of immunes in Seattle. I do not know anything about the application to the whole State. The rate is very remarkable.

Doctor CUMMING. Doctor Turner would tell you it is the absence of deaths up there in the Puget Sound district. Is there any further discussion?

(No response.)

The next subject on the program, which is "Child hygiene," will be postponed until this afternoon. We will take up, with your permission, the question of "Malaria," Doctor Fricks.

MALARIA.

Doctor FRICKS. Mr. Chairman and members of the conference, it is a pleasant task to discuss the affairs of a going concern at a meeting of the stockholders and their associates; therefore I am pleased indeed to talk to you to-day about our cooperative program for malaria control, which has been unquestionably a very successful business venture looking to health improvement in the South. I am told that this cooperative program for malaria control has returned huge dividends to some of the health officers who have entered into it, particularly in the way of public approval of their activities, and in no State, so far as I know, has it been a liability or hindrance to the State health officer in carrying out his general program for health improvement. I appreciate the fact that not all of you State health officers are directly interested in malaria control, but I feel sure that you are all interested in the successful working of a cooperative agreement such as the Public Health Service, the International Health Board, and the different State health authorities have entered into for malaria control.

Ten years ago governmental, State, and private health agencies began to realize that little was being actively done toward the control of malaria in the United States, although it had been demonstrated conclusively that malaria could be controlled in the Tropics, where presumably the problem was more difficult to handle. Following the methods which had been employed for malaria control in the Tropics, the Public Health Service and the International Health

Board assisting, the various State and local health officials concerned began making demonstrations in urban malaria control at many places in the Southern States. These demonstrations were generally successful, and in most instances the community immediately concerned was highly enthusiastic over the results accomplished.

At this time, however, no definite program for a fixed and permanent policy for continuing and expanding these malaria-control demonstrations was entered into by the cooperating agencies, and although, as before stated, most of these demonstrations were highly successful, they did not lead up to the establishment of permanent programs for malaria control by the different State health authorities. Three years ago such an arrangement was entered into by the cooperating agencies with the health authorities of 10 Southern States. Thus our cooperative program for malaria control was begun, the success of which has been to me most marvelous. Our foundations were sound, of course, because we had been conducting successful demonstrations in urban malaria control for several years. We knew that these could be relied upon. We also had considerable experience in temporary campaign for health improvement conducted by outside agencies in other fields and thereby knew some of the mistakes which must be avoided. It may be that our cooperative program from a business standpoint is a cumbersome arrangement, but we have had no serious difficulty among ourselves in settling the small matters which have come up from time to time. We all see clearly the objective which we have in view—malaria control and the strengthening of the different State health departments engaged in this work. It may be, perhaps, that if we had entered into our cooperative agreement with only one idea in view—that is, malaria control—by traveling alone we might have traveled faster in a sense, at least, but when the greatest good is properly weighed and the largest results are considered, I feel that our policy of helping the State health authorities to graft malaria control onto their general program of health work has proved the wisest and most beneficial in the long run, and I believe that the progress of our cooperative malaria control work during the past three years has demonstrated the wisdom of our policy.

Up to the time that our cooperative agreement was entered into many sporadic attempts at malaria control in the Southern States had been successfully completed, but no State had outlined or adopted a definite program of malaria control. Now every State, possibly except one, that has a malaria problem has also a malaria program with personnel and funds allotted for carrying it out, and no State which entered into the cooperative agreement has taken its 'hand from the plow."

In the beginning we realized that cooperative malaria control would be developed along different lines in the different States, because their problems would be somewhat different, and not all of the States had reached the same point of development in their general health work. I have always felt that ultimately malaria control must fit in closely with other rural health work, but it was necessary for us to begin our cooperative malaria work on a basis of urban demonstrations, because previous experience had demonstrated that such demonstrations were feasible, and we were in a position to furnish expert assistance by sanitary engineers who had been trained in work of this character. Hence several of the States found that malaria control could be best conducted under the division of sanitary engineering, while in some States the work has already been placed under the division of rural sanitation.

I shall not take time to enter into the details of our cooperative malaria control work in each State. Some of the State health officers most vitally interested are here and can tell you what is being done in their respective States. I would like to impress you with the fundamental idea of our cooperative agreement, which is that it is the duty of the State health officer to outline the policy and determine the direction under which malaria control should be conducted in his State in order to correlate this work with other health activities and insure its permanency. As an index of the progress which has been made in cooperative malaria control work, I shall give you a very few figures. Upon inquiry we secured records of expenditures for malaria control during 1921 of more than $270,000, which had been locally appropriated. These records are undoubtedly incomplete. This year, 1922, three of the States which are undertaking cooperative malaria control have appropriations or allotments amounting to $10,000 each for malaria control; four States are contributing $5,000 each for malaria control; and two others $2,500 each for malaria control. Thus we have in 1922 from $55,000 to $60,000 set aside by southern States for malaria control, whereas previous to three years ago no State had a definite appropriation for this purpose, so far as I know. Since the cooperative agreement was entered into, three additional States have come into the work—Missouri, Illinois, and Kentucky—so that we now have 13 States interested in malaria control and carrying on a definite program with that end in view. In fact, every State in the Union in which malaria is of sanitary importance is now doing something for its control, except possibly Florida. We have no working agreement with that State, and therefore I do not know what is being done there.

In my judgment, the remarkable success of our cooperative program for malaria control is based upon the fact that there is a widespread demand for malaria control throughout the South, efforts for the control of this disease having lagged behind other health activities in every State. Also, we had our past experiences in other health campaigns to profit by, and have conducted this one on the basis that each party cooperating must contribute something and must carry a definite part of the load.

In addition to supervising the cooperative work of malaria control, the Public Health Service has also conducted certain investigations pertaining to malaria in which you will no doubt be interested. I shall barely mention these investigations, because while they are of greatest importance they are still under way and will be the subject of future reports. One of the subjects under investigation is the importance of malaria on the growth and development of children. I do not believe that this matter has been given the attention in the past which it deserves. Certainly, where malaria infection is heavy the majority of the children are infected quite early in their lives, and heavy infections among children must seriously interfere with their growth and development. A study of malaria among the school children of the South has been undertaken, and in cooperation with Dr. Taliaferro Clark, of the Division of Child Welfare, these studies will be carried on with the care to which they are entitled.

Another investigation in which the service is deeply interested is that of malaria prevalence and malaria reporting. We all realize the inadequacy of our malaria morbidity reports. Most of us appreciate the difficulties encountered in attempting to determine the amount of malaria present in any community by any or all of the methods which have been employed for this purpose. Asst. Surg. K. F. Maxcy of the service has been assigned to the study of this problem, and it is hoped that he may find some fairly easy yet effective method of determining the amount of malaria present in a community.

Another subject still under investigation is that of Paris green as a larvicide. You all know that we have used oil for this purpose since Dr. L. O. Howard first described its use many years ago, but oil has many limitations. Two years ago Dr. M. A. Barber began a series of investigations of larvicides for the service. Doctor Barber soon found that Paris green in extremely minute doses was a very effective anopheline larvicide. There is no question whatever as to the killing effect of Paris green on mosquito larvae in very minute doses, but Doctor Barber is continuing his investigations for the purpose of determining the most effective manner of using or distributing this poison. His investigations have already been reported, and future findings will be brought to your attention through service publications.

I thank you.

Doctor CUMMING. Mr. Fisher will speak on "Methods of evaluation of results of local measures for the control of malaria."

(Mr. Fisher thereupon read his paper.)

METHODS OF EVALUATION OF RESULTS OF LOCAL MEASURES FOR THE CONTROL OF MALARIA.

Before attempting to discuss the methods for evaluating the results of local measures for the control of malaria, let us examine briefly why there should be any evaluation of such results.

The first reason for evaluating results or for measuring accomplishments comes from the desire to know whether the results attained are commensurate with the effort expended. To answer this question it is necessary to have rather a clear understanding of what is included under the designation of results. By effort expended we mean voluntary effort as well as paid effort. In malaria control work, perhaps more than in some other lines of health work, the financial value has come to be emphasized more than the humanitarian value. Whether this is fortunate or unfortunate is a moot question. In this highly commercialized age it would be very difficult in some quarters to inspire any work on humanitarian grounds alone if there were no financial reasons to urge. However, in considering results accomplished we can not afford to lose sight of the humanitarian results.

In considering both the financial and the humanitarian results we must bear in mind that there are direct and indirect benefits of malaria-control work and that the indirect benefits are none the less real because they are indirect.

It is perhaps needless to say that any measuring of accomplishments should be unprejudiced. It is well also to remember that many results are difficult of measurement because we have no well-adapted measuring stick. This difficulty accounts perhaps in great part for the tendency of measuring all results in malaria-control work by the yardstick bearing the dollar mark. This measure is at least one in frequent daily and widespread use, and on that account more readily understood than some other methods might be. Such results as can be stated in terms of dollars and cents, therefore, should be so stated because they will be perhaps more widely understood than if stated differently. People appreciate money, it seems to me, even more than they appreciate life. You can prate about so-and-so many lives saved as a result of your work and you will favorably impress a small group of sympathetic hearers, but when you speak of thousands of dollars saved you get a far wider hearing.

Moreover, because malaria does not kill as many as it temporarily incapacitates the results of such incapacitating, if economically expressed in money losses, appeal to a larger number of people.

If we examine the results of malaria-control measures, we find that there are both direct and indirect results. Some of them are difficult of measurement. This is true of the direct results as well as of the indirect results. Some it is impossible to measure in dollars and cents.

Among the results to be considered and methods of evaluating them may be mentioned—

1. A marked decrease in the number of malaria cases, resulting in an economic saving due to the saving in—

(*a*) The sum spent for drugs.

(*b*) The sum paid for doctors' or nurses' fees.

(*c*) The sum lost because of inability to engage in productive labor.

2. There is a decrease in the malaria death rate resulting for each death in a saving equal to—

(*d*) The same saving as accrues for the preventor of a case of malaria, plus
(*e*) A sum representing the economic value of a human life.

The best method of arriving at these figures is probably by a house-to-house census. If the community is large, it may not be feasible to go to every house. In such a case districts should be selected representative of the whole population and a census made in these, assuming that the figures so obtained bear the same relation to the true total figures as the population canvassed bears to the total population of the town. This census may include figures for the preceding year. But such figures will be less exact than figures for the current year, because one remembers more vividly what happened this year than last.

There are, of course, a number of objections to taking a census in this way. Possibly the chief one is the ignorance and suspicion encountered among certain elements of the population, tending to produce untrue results. If the census is taken by a stranger, the persons questioned may resent what they may regard as a prying into personal affairs. The same objection arises sometimes when the census is taken by an acquaintance or a native of the town.

It is important in gathering and compiling information that it be obtained in the same way before and after measures are undertaken. This is advisable in order that such errors as are made the first time may be made the second time in the same way, thus compensating each other. In this way the results will be comparable; otherwise they will not.

Still another objection to this method of obtaining information with reference to the former and the present prevalence of malaria is due to its inaccuracy. It should be remembered in this connection, however, that there is no absolute accuracy in any method of obtaining information. If blood examinations were made of every person in the community before the control measures were instituted and again afterwards, they would not be absolutely accurate. We must, therefore, be satisfied with a method that is—

(1) Feasible.
(2) Gives comparable results.
(3) Insufficiently accurate for the purpose intended.

It should be noted that the purpose for which the figures are intended have much to do with the method of obtaining the figures. There are occasions when the most accurate investigations, carried out by the most careful and most skilled observers, are justified. But the instances in which such methods should be employed in evaluating the results of local measures for the control of malaria are rare because of the expense involved.

Frequently the results will be used to obtain appropriations with which to maintain work already done. In dealing with appropriating bodies, the facts should be so stated as to be clearly comprehended and so as to admit of no misconstruing, either willful or unintentional.

The whole-hearted statement of the mayor or some other prominent person in a neighboring town giving his valuation of the work carried out in his own town will have more weight with a council considering the advisability of making a first appropriation than a compilation of the results of blood examinations. Similar statements obtained from physicians with reference to the effectiveness of control measures are of great value. Such statements are regarded as coming from expert witnesses. Sometimes the witness is not entirely unprejudiced and its statement is affected accordingly. I have heard some statements coming from enthusiastic physicians which I found it difficult to believe. On the other hand, I heard some which were plain untruths. The latter kind of statement we usually try to disprove because it hurts the work. We don't say much about the other kind.

3. As a third result there is the increased property value accruing because of the removal of the health menace and of the mosquito nuisance. This is measured in increased rental value and is difficult to establish.

4. Then there is the increased value to property arising from the reclaiming of land for agriculture. Some of this value can be ascertained, because the growing crop where formerly mosquitoes developed can be evaluated. This increased value is sometimes estimated by real estate dealers, landowners, or by the property owners themselves. It not infrequently amounts to more than was actually spent on the whole undertaking. The question arises, "Why, if there is such an obvious material gain, was the work not undertaken sooner?" I think there are several reasons. One undoubtedly is due to a trait frequently found in human nature whereby we are loath to contribute willfully to an effort in which our neighbor benefits more than we do, particularly if we believe that our neighbor has a reputation for being stingy or if we think that he has in some way offended us in the past.

Second, it requires a certain amount of time and effort to work out a program that includes the whole community, and frequently the community does not contain the individual sufficiently altruistic, sufficiently patient and long-suffering to endure all the scathing statements with reference to the ulterior motives said to be actuating him to carry the work to completion.

Again, legal obstacles may exist which community enterprise unassisted can not surmount.

I believe that along these lines lies the State's greatest opportunity to reduce malaria, since the appeal can be made to agricultural improvement as well as to health advancement. The work will be largely self-sustaining, in that much of the cost of eliminating malaria will be charged to agricultural development.

5. Among the indirect results which accrue and which are difficult of evaluation but are of great value to the community is the reputation for healthfulness and for progressiveness which comes to the community because of the control measures it carries out. The health authorities should perhaps not be called upon to measure this benefit. Rather it should be worked out by some civic or commercial organization, such as the civic league or chamber of commerce.

Instances have come to our attention where civic development utterly impossible without control measures have immediately taken place after the control measures were successfully instituted.

6. Another important indirect result comes from the savings arising because of increased bodily resistance to other diseases. This is comparable to the like indirect gain resulting to a community when water-borne typhoid fever prevailed until the installation of a safe water supply put a stop to the recurring epidemics. In the case of typhoid fever it is pretty well established that the general death rate is reduced. Is it also true when malaria control measures are instituted? It is logical to believe that in the case of malaria the results will be more noticeable than in the case of typhoid fever.

Before this effect can be measured we must have vital statistics covering a number of communities over a period of years. I do not know of any such statistics now being collected. I think the subject is worthy of study.

Still other indirect gains arise from various lines of increased productivity made possible by full-time labor and more efficient labor. Some of these gains can be measured, others are practically impossible of evaluation. Briefly enumerated they are:

1. Increased production of manufactured goods.
2. Cheaper production of manufactured goods.

Various ways in which the community is benefited thereby are: (*a*) More profit for merchants because of larger volume of goods handled; (*b*) more freight for railroads; (*c*) more discounts for bankers; (*d*) more employment of labor to handle goods; (*e*) better opportunities for professional men; (*f*) more days at school for children; (*g*) better roads, due to better drainage; (*h*) better schools because more tenable property is available; and so on. The enumeration is almost endless.

3. Lastly there results a community spirit of cooperation which makes possible community undertakings previously not thought of. This is particularly true in matters pertaining to public health. "The fly problem must be solved next. If we can eliminate mosquitoes" reasons the community, "why not flies." As a result the town is cleaned up. The health department is revivified. A new spirit is abroad.

To measure these results accurately is difficult, but we know they exist and they contribute tremendously to the good will of the State and Federal health organizations outside of the community that have made the work possible.

In summing up, I should enumerate the methods of evaluation of results of local measures for the control of malaria.

1. A history index made by as intelligent workers as are available, showing essentially:

Location of house.
Number of cases in the family, this year, last year.
Length of residence in the community.
Previous history of malaria.
Economic loss due to drugs, fees, lost time.

This index to be prepared both before any measures are undertaken and about a year later, and again during the following year.

2. Definite statements from physicians with reference to the reduction of malaria cases in their own practice.

3. General statements from leaders in the community with reference to their own observations both as to the amount of malaria and as to the value of measures instituted.

4. Statements from civic or commercial organizations who have studied the effect of the measures carried out.

5. Point out towns which are spending money yearly on maintenance work in order that there may not be a recurrence to former conditions.

Doctor **Cumming.** Doctor Ferrell, would you like to discuss Mr. Fisher's paper?

Doctor **Ferrell.** It is probably not in order for me to attempt to discuss these papers, because the State health officers under whose general supervision the work has been conducted are present and are well qualified to present the facts. Moreover, Doctor Fricks, who devotes his entire time to the malaria work, has presented a most interesting account of the activities.

Two points occur to me which should be of general interest. One relates to the demonstrated feasibility of three or more agencies cooperating harmoniously in a common task. In the Southern States during the past three years the Public Health Service, State boards of health, selected counties and towns, and the International Health Board have worked in complete harmony and through joint effort have made gratifying progress in controlling malaria.

The second point was touched upon by Mr. Fisher. All executives responsible to the taxpayers and legislative bodies are interested in the development of methods for determining the public health importance of a given disease at a given time, the progress made in its control, and the cost of obtaining control. Evidence which is more tangible than is general opinion should be collected. The gentlemen from Virginia and North Carolina have presented figures for measuring results which should have suggestive value. It may not be feasible to collect accurate information for the entire work, but it should be practicable to collect definite information for sample areas.

It has been a satisfaction to me as a representative of the International Health Board to work with the Federal, State, and local health officers who are responsible for the gratifying progress that has been made in this field.

Doctor CUMMING. I think that Alabama has done more than any one State, from what I hear, during the last few years. We shall all be glad to hear from Doctor Welch.

Doctor WELCH. I want to show you by these charts what I think is very largely true of the entire Southern States. The South stands convicted of having malaria, typhoid fever, and hookworm disease. We have pleaded guilty to the indictment and have gone about removing the stigma in a systematic manner. This chart shows the distribution of deaths in Alabama in 1917 before any work was undertaken.

This chart shows the number of deaths for 1921.

You will observe that there are 530 red dots on the 1917 chart. There are 231 on the 1921 chart. In the hill counties of Alabama there is practically no malaria now. It has been expelled in the last few years. There are still areas of heavy infection along our river fronts and in the swampy areas of the State. You will observe by this chart the area of heavy infection. We are attacking these strategic points on the theory that if we expel malaria from these heavily infected areas there will be a tendency for it to disappear from natural causes in the other sections. Malaria is coming rapidly under control in Alabama, and we believe that in a few years we will have come out from under this handicap under which we have labored for the last century.

I will say to the smiling cynics before me that the State board of health did have a part in lowering the death rate in Alabama from malaria. It is at least getting the credit for it down there.

In my opinion, the chief factor in this rapid reduction is due to the fact that during the war, at Muscle Shoals, Camp Sheridan, and Camp McClellan, the United States Public Health Service did some very effective malaria-control work. In 1916 the impounded waters of Lock 12 on the Coosa River were stocked with top feeding minnows, and from this center they have been distributed to the streams all over the State.

Discussing the other problems of the South, I have here an interesting chart which comes to me from my predecessor. A laborer came to this sawmill camp infected with typhoid fever. The stools were thrown into this marsh, which communicated with this creek. The water in the well which supplied the sawmill was exhausted. A ditch was cut to the creek and the water from it conveyed to the well. Three-fourths of the hands working at the sawmill went down within three weeks with typhoid fever, and one-fourth of those infected died.

We have a splendid system of control of municipal water supplies. As a result of that control there were 989 deaths from typhoid fever in 1917 and only 372 in 1921. This work I am showing graphically is the character of work being done by all the boards of health in the Southern States. We have accepted our problems. When we have successfully solved our malaria, typhoid, and hookworm problems, as we surely will, our health problems will then not differ from those of other parts of the United States and the South will come into her own again.

Doctor CUMMING. Doctor McCormack, of Kentucky.

Doctor McCORMACK. I am rather inclined to think that in the long run those of us in the malaria and hookworm and rather large typhoid fever area of the United States will be very fortunate, because it is much easier for us to demonstrate to our people rapid and marked progress than it is in the sections that are so unfortunate as not to have these dramatic diseases, and therefore we are able to secure a degree of public confidence rather more rapidly than they are able to furnish us with money.

Having been in some 25 States during the past year, I have been impressed with the tremendous progress that is being made to-day by the health organizations of the United States. It seems to me that it is of the utmost importance that we formulate our plans for the State, so as to do our job better every day, and that in the increasing personnel that is being demanded by the people we develop that personnel so that it is competent and delivers the goods in its individual unit in practically every instance. We can not afford to make a mistake. We can not afford to furnish through these people incompetent health officials and accept the responsibility for them. We must build our agencies, if necessary, rather slowly to meet the popular demand.

The cooperation between the United States Public Health Service and the States and the localities seems to me to be the most important prospective development of the future. At the recently adjourned conference of State health authorities I do not think anything more important was considered than the memorial to the Congress thanking them for the Federal aid which has been extended to the States where great progress has been made, but requesting Congress and the Executive to study the entire health problem presented in these United States and to formulate such a general plan of coordination and cooperation as will assist in stimulating the development of some sort of competent local health agency that will be available for every citizen and every resident in the United States. Our plan should be developed broadly, and I believe it is important for us to come in contact with Senators and Congressmen. They are always glad to have us and have our advice. They know very little about these special problems unless they get that information from one of us, and we have been rather backward sometimes, it seems to me, in going to our statesmen whose first desire naturally is to take care of the people who elect them to office.

We have been a little remiss, I suspect, in giving to them the information which we have which would be of enormous interest and value to them if it were presented to them by those of us in whom they have confidence. Of course, if you do not know your Congressmen and Senators, if they do not believe in you, it is better for you not to talk to them; but if they do, and you have not charged them with the knowledge that you have, it seems to me that in that way you are derelict in a big part of your duty.

In recent conferences in various parts of the country public-health nurses who were acquainted with representatives in the State legislature talked to them about health and their social problems. I want to say that if you have not talked to your Senators and Representatives, and if you have not talked to your representatives in the assembly of the State, it is just like trying to write on blank paper with a pencil without a point. It is important for us to take our movement forward very rapidly if we are going to make real progress. I want to appeal to the health officers of this country to feel the tremendous responsibility, not alone for the scientific, patriotic, and statesmanlike work that we are doing from our offices but for making the right impression on the public. That is our first responsibility, and unless we do take an active interest in it we can not make progress as rapidly as we desire. On the other hand, we must not get too far away from our load. I like to remember our country fellows. If you hitch your team too far from the load, you either break the traces or stall the team. You do not want to get too far ahead of public opinion, but you should keep on educating public opinion so it keeps up with you; but be sure to educate legislative opinion so it keeps up also. The most important result of such a conference is not only the mutual acquaintanceship, the general rivalry stimulated by such a demonstration as this health officer from Alabama suggested, but confidence in one another and mutual knowledge that the problem that confronts any of us in any State in the Union is the problem of every health officer. We must make the Congress help us build an organization that will make the United States the healthiest, happiest, and best nation in the world.

In Portland I was speaking to a city club that made a remarkable study in cooperation with the service of sanitary conditions in Portland. I spoke that day on the same program with the president of the University of Bombay, and in his opening remarks he said that he represented an institution that had existed continuously for 7,000 years. It made us feel very young. At the end of 7,000 years I would like to see America a nation whose destinies were not presided over by some foreign potentate; I would like to see America still have its place in the sun and still helping to control the destinies of mankind. If we are to do that, we must train our whole citizenship.

Doctor CUMMING. If I had time, I would get Doctor McCormack to tell you what the chairman of the Appropriations Committee told him. Doctor Fulton will now talk to you about the registration area for morbidity.

REGISTRATION AREA FOR MORBIDITY.

Doctor FULTON. The Surgeon General's office and the delegates to this conference have been patient and considerate toward me during six or seven years past. Nearly every year I have summarized the morbidity reports turned in by the States and cities to the Surgeon General's office in such fashion as to indicate the order of merit of so many attempts on the part of 34 States to inform themselves about current morbidity.

Each year I have proposed the formation of a registration area for morbidity to be located in the United States Public Health Service of the Treasury Department.

During the last five years I have considered it quite feasible to create such a registration area, the conditions being, in my judgment, quite as favorable as the conditions under which the United States registration area for mortality was created in consequence of an act of Congress passed in 1902 and giving us, in 1906, a first volume of mortality statistics, covering the annual mortality for four years (1900–1904) in an area comprising only 11 States and a number of cities in nonregistration States.

The creation of a registration area for births (1915) was effected under conditions less favorable than the Treasury Department now confronts in planning a registration area for morbidity.

The Surgeon General's office is not destitute of knowledge concerning current morbidity. It does not receive this information in such a way nor has the office internal arrangements or personnel sufficient to produce annual publications of the kind we are familiar with in accounting for births and deaths.

I sincerely hope that the conference will not adjourn without placing as heavy a load as the delegates present can reasonably impose upon the Surgeon General's office concerning this project and that everyone will get behind the Surgeon General. He may have space and personnel, though I doubt it. Certainly he will need additional funds.

Finally, remember this, that the conference, in assenting to delay, willingly or unwillingly delays the project not for a year but for two years. When authority and means are at length provided we shall wait at least 18 months for a first report of the Surgeon General on the registration area for morbidity.

Doctor CUMMING. Doctor Warren.

Doctor WARREN. The Public Health Service has, as Doctor Fulton knows, been endeavoring to get appropriations for six or seven years to start the registration area for morbidity. During the war everything went for the war; there was no extra money except for war purposes. Since the war there has been economy, but I believe that during the coming year or so the Congress will let us have some appropriations for this purpose.

The Congress has placed these appropriations back on a pre-war basis, and that is where we are now, without any funds; but the Public Health Service has endeavored to assist in this line in getting better morbidity reporting by means at hand. For example, there are now only four States east of the Mississippi River and two States west of the Mississippi River without collaborating epidemiologists of the Public Health Service. The number in the States is gradually increasing. We now have between four and five thousand collaborating and assistant epidemiologists; and if you will notice morbidity reports, they have been increased over 100 per cent in the last six or seven years, or more than that.

In regard to doing something without funds, we thought at one time, after the last conference, that we would start something in the way of getting at the morbidity by means of the weekly morbidity occurring in 100 cities in the United States. We sent out letters to the State health officers with that in view. We realized that to get these morbidity reports promptly we would have to in a way get the reports direct from the cities. We put up to them, owing to the urgency of getting a quick report, the question of having the cities send us a telegram every Monday morning and mail a copy of that telegram to the State health officer, but it did not get their approval. I do not blame the State health officers. From their viewpoint it was not the best policy, and so we let it go at that. So many of them objected to it that we decided not to push it any further. We do receive on Monday and Tuesday of each week telegrams of the reports from quite a number of States.

The following is a list of States showing they have reported for the 17 weeks of this year:

Alabama has reported on time 16 times, 1 time late; Arizona has made no report; Arkansas has reported all reports on time; California, all reports on time; Colorado, on time 16 times, 1 time late; Connecticut, all reports on time; Delaware, 14 times on time, 1 time late, and 2 reports not received; District of Columbia, 17 times late; Florida, all reports on time; Georgia, all reports on time; Idaho, no report; Illinois, all reports on time; Indiana, all reports on time; Iowa, all reports on time; Kentucky, 17 times late; Louisiana, 16 times on time and 1 time late; Maine, 12 on time and 5 late; Maryland, all reports on time; Massachusetts, all reports on time; Michigan, no reports; Minnesota, all reports on time; Mississippi, all reports on time; Missouri, all reports on time; Montana, all reports on time; Nebraska, all reports on time; New Jersey, all reports on time; New Mexico, all reports on time; New York, all reports on time; North Carolina, all reports on time; North Dakota, no report; Ohio, no report; Oregon, all reports on time; South Carolina, no report; South Dakota, all reports on time; Texas, all reports on time; Vermont, all reports on time; Virginia, 9 reports on time, 8 reports not received; Washington, all reports on time; West Virginia, 16 reports on time and 1 time late; Wisconsin, all reports on time; Wyoming, only 2 reports received.

Of course, the morbidity reports, as received, are not satisfactory, but it shows the State health officers are trying to cooperate and send us what they have, and we publish those reports, if they are received on time.

In connection with the obligations to collect morbidity reports, which have been imposed upon the Public Health Service by acts of Congress and treaty obligations, the following letter of the Surgeon General is published as explaining in full his position in this regard:

JUNE 22, 1922.

Dr. A. J. CHESLEY,
Secretary State Board of Health, St. Paul, Minn.

DEAR DOCTOR CHESLEY: I wish to acknowledge the receipt of your letter of June 14, relative to the collection of morbidity reports by the Public Health

Service from the cities of the United States. I have before me the resolution adopted by the thirty-seventh annual meeting of the Conference of State and Provincial Health Authorities of North America, relative to this subject.

In a general way, I may say that I agree with the principles contained in the resolution relative to State health work, but it did not occur to me at the time I agreed to the resolution of the State health officers that the Public Health Service has certain duties to perform under the acts of Congress which do not relate to State health work, such, for example, as national quarantine, prevention of interstate spread of certain diseases, and the carrying out of treaty obligations of the United States. In performing these functions, however, I wish it clearly understood that it is my desire at all times to execute these duties in cooperation with State and local health authorities. I realize that it is by teamwork that the health protection of the citizens of the United States can best be accomplished.

Occasionally in the history of the Public Health Service questions as to the methods of cooperation with State and local health authorities have been brought to the attention of the bureau by resolution or otherwise. In many instances, as in this resolution, those who drafted the resolutions did not have the background of knowledge or experience as to the duties and obligations of the service under the acts of Congress.

The act of February 15, 1893, provides, among other things, as follows:

"* * * and the Secretary of the Treasury shall also obtain through all sources accessible, including State and municipal sanitary authorities throughout the United States, weekly reports of the sanitary conditions of ports and places within the United States, and shall prepare, publish, and transmit to collectors of customs and to State and municipal health officers and other sanitarians weekly abstracts of the consular sanitary reports and other pertinent information received by him, * * *."

Under the international sanitary convention signed at Paris January 17, 1912, the United States obligates itself to furnish to the other powers signatory to the treaty information as to the sanitary conditions in the United States. You can readily understand, therefore, that the collection of morbidity reports is a Federal obligation, as well as a State and local one. As a Federal obligation it has nothing to do with the police powers of the State and is not an interference on the part of the Federal Government in the State police powers, and is clearly within the duties which might be expected of the United States, especially in its relations with foreign countries.

The Public Health Service has been receiving these reports from the cities as far back as 1888. The reports, of course, were very meager at that time, but they have been increasing in volume and improving in reliability until at the present time, out of 755 cities in the United States with a population of 10,000 or more, the Public Health Service is receiving regular reports from 264 cities, and fairly satisfactory reports from 291 other cities, or a total of 555. These reports are published weekly in the Public Health Reports and the annual reports received from these cities are published annually. I am inclosing a copy of the Public Health Reports for June 9, 1922. By reference to that report you will find the annual report for cities of 100,000 population and over, covering some 20 pages. In the same report you will find the weekly city reports for the week ended May 20, 1922, covering 12 pages. A further reference to this issue will show you a weekly report received from the States. This covers five pages. In the same issue you will find the Health Index compiled each week by the Census Bureau from the city reports. I understand that the Census Bureau in establishing its registration area for mortality reports does not always work through State health departments.

In collecting the morbidity reports from cities, the Public Health Service desires to obtain three classes of information:

1. The number of cases of communicable diseases reported to the city authorities each week.
2. The number of deaths from the communicable diseases reported.
3. The number of deaths from all causes.

For your information I am inclosing a card used by the service for this purpose, a supply of which is sent to all of the cities in the United States of 10,000 population or over. These cards, when filled out by the city health authorities, are sent directly to the Public Health Service. Up to the present time there has been very little complaint on the part of the State that such reports interfere with reports of the same cities to the State departments of health. When such complaints come from the State departments of health to the Public Health Service, they are informed as to the purpose of these reports. In such cases the State departments of health are also informed that cities in the said States would be advised to discontinue such reports to the Public Health Service, provided the State departments of health could furnish the same information as promptly and as accurately as the information received from the cities, thus enabling the Public Health Service to perform its duties under the law and carry out the treaty obligations of the United States in regard to international sanitary agreements.

Up to the present time three States have agreed to furnish the desired information from cities within their jurisdictions. These three States, however, have not up to the present time succeeded in furnishing the information as desired. One difficulty which seems to lie in the way of the States furnishing this information promptly and accurately is the fact that the death reports do not appear to be available for insertion on the card. Another difficulty is that in the rush of other work in the State department of health there results a considerable delay, especially in times of an epidemic, when the information is particularly desired.

Recently a certain State department of health made a complaint similar to yours, but when advised as to the character of the information desired, the secretary of the State board of health withdrew his objections.

If Minnesota is able to furnish the information desired of all the cities in its jurisdiction of 10,000 population and over, the Public Health Service will be glad to collect this information through your office, but you can readily see that under the act quoted above the Public Health Service is commanded by the Congress to obtain this information through all sources accessible, including State and municipal sanitary authorities. Where States are willing and able to furnish the information required under the law, it is a much more desirable method of collection. But where States are unwilling or unable to furnish the information, it is a mandate of Congress to the Public Health Service to seek to collect this information from municipal sanitary authorities.

Respectfully,

H. S. Cumming, *Surgeon General.*

Doctor Cumming. If there is no discussion, we will now take up the topic "Venereal diseases, the proposed program for the ensuing fiscal year."

PROPOSED PROGRAM FOR THE CONTROL OF VENEREAL DISEASES.

Doctor Pierce. Day before yesterday six of the State venereal-disease control officers were in conference practically all day with me and with other members of the staff of the Venereal Disease Division. The State venereal-disease directors present were from New York, Pennsylvania, Mississippi, New Jersey, Indiana, and North Carolina. That night three State health officers, Doctors Olin, McCormack, and Crumbine, met with us and discussed a program for next year. At this conference we reviewed the work that had been done during the past year and the State programs already in operation, and also discussed in some detail various phases of the program that all of us agreed should be emphasized during the coming year.

In order to carry on any practical program in any State money is required. Most of you know Congress appropriated $225,000 for allotment to State boards of health for venereal-disease control work during the fiscal year beginning July 1, 1922. I am sorry that this amount is not larger, as it figures out a little less than one-fourth of a cent per capita of population. The allotment due each State was printed in Public Health Reports for May 5, 1922. Shortly after you return to your homes you will receive a letter from the Surgeon General setting forth the exact amount to which each State is entitled and the provisions under which it can be obtained. An equal amount must be appropriated or otherwise set aside by the State for expenditure for venereal-disease control work under the direction of the State board of health.

The regulations governing the payment of the allotment will be the same as they have been for the past four years, with a few modifications made necessary by the fact that the appropriation this year was made in the Treasury Department bill and will be handled by the Public Health Service. A plan for paying these allotments to the States was submitted to the Comptroller General of the United States and was approved by his office and by the Secretary of the Treasury. This plan provides that allotments will be paid quarterly in advance. Before the State is paid evidence must be furnished to the Surgeon General that an equal amount of State funds are available, and a budget is to be prepared and forwarded to the Public Health Service showing the manner in which it is propsed to expend the joint fund. State funds in excess of the Federal allotment should not be included in the budget, nor should the expenditure of such funds be reported to the Public Health Service, except as a matter of interest and as evidence of work accomplished by the State.

After the first quarterly installment of the allotment has been paid to a State, all vouchers will be settled by the State and not sent to Washington for payment. A monthly report of disbursements made from the joint fund will be required.

There are three things that can not be bought from the joint venereal-disease control fund—buildings, land, and automobiles—as congressional restrictions apply to the joint fund.

Having disposed of the financial phase of this matter, let us consider briefly the program for next year. The six State venereal-disease control officers and the three State health officers participating in the conference of day before yesterday have practically agreed upon the basic principles of the program for the coming year. Please remember during this discussion that the suggestions made are largely generalities and that the details regarding the application of these principles are left to each State. All of us feel that it will be well worth while to devote considerable thought, energy, intelligence, and supervision to the question of interesting private practitioners throughout the country in venereal-disease control and to endeavor to see that doctors give better treatment to these cases in the future than they have in the past. We believe that 90 per cent of the venereal-disease cases will be treated by general practitioners, not by specialists. This is a condition that we can not change, and therefore we should get the general practitioners to adopt better methods of treatment. We should also impress upon them the importance of the social phase of venereal-disease control to a much greater extent than is appreciated at the present time. By social phase, I refer to ascertaining the sources of infection and efforts to prevent the spread of venereal diseases. Certainly, when a married man or woman or a child is under treatment for a venereal disease the doctor should inquire into the history of the case and examine the other members of the family to bring them under treatment if necessary.

All of us agreed that the work of the divisions of venereal diseases in the various State boards of health should be linked up with the work to be done in your State under the terms of the Sheppard-Towner Act. If you endeavor to prevent infant and maternity mortality and to bring about conditions which will benefit the new-born child, there is no other one activity that plays a larger part in such a program than control of venereal diseases, particularly syphilis. There is a good deal of statistical data available on the relation of syphilis to infant mortality. Such data has been collected by Dr. P. C. Jean, of St. Louis, and Dr. Whitridge Williams, of Baltimore. At the present time a letter is being prepared which will be sent to all State health officers inviting attention to the importance of venereal-disease control in any program to promote infant and maternity welfare. This letter is based on data we have collected and on the opinions of the leading obstetricians of this country. Just how to link up venereal-disease control work with infant and maternity welfare work in the State is something for each health officer to work out for himself. We desire to recommend that you devise some plan to make these two divisions of your State board of health function coordinately.

Another point we all agreed upon was that every effort should be made to develop the venereal-disease control program as a local community responsibility. We want to get each town and county of every State to bear its own financial burden and to provide treatment for infected persons; to carry on preventive work; protective social work; educational work; and all the phases of the program. Each community should be willing to assume its local responsibility in relation to protecting the rest of the community against venereal diseases, just as they do for all other communicable diseases.

The fourth point discussed and upon which we agreed was that we recommend to State health officers that the venereal disease control program should be carried on as nearly as possible in the same general manner that all other communicable disease control programs are conducted. We should not expect to continue indefinitely to make provision for a special agency in each State for venereal disease control. Such work is really a part of the work of the communicable disease bureau or division. During the past four years we were quite justified in making venereal disease control work a special division of the State board of health because the problem had been neglected previously, but we must now look forward to the time when such work will become a part of the bureau of communicable diseases, to the time when gonorrhea and syphilis will be controlled as are other communicable diseases.

I would like to point out that when you agree to this proposition of putting venereal disease control on the same basis as the control of other communicable diseases, more attention must be paid to the sources of infection. When you find a case of smallpox, whether it be in a house of prostitution, in a restaurant, in a hotel, or in the city, you institute proper measures of isolation to prevent any spread of the disease. When these communicable diseases, gonorrhea and syphilis, are handled as other communicable diseases by the health office, it can not be said that suppression of the prostitution is a matter to be handled only by the police and law-enforcement agents. If we treat syphilis and gonorrhea like we treat other diseases, the health department has a great deal to do with the suppression of all forms of prostitution. This does not mean that I advocate raids on houses by the health department. We must, however, see that the proper local authorities perform their duty in regard to destroying foci from which venereal infections spread. Health departments must assume certain responsibilties in connection with eliminating vice conditions in the community if we are going to treat gonorrhea and syphilis like other diseases.

All of us agreed that the educational program carried on for the past four years is a necessary part of venereal disease control work. In fact, at all recent public-health meetings it has been emphasized that public health is a matter of education, and that a well-informed public can avoid not only venereal diseases but all other communicable diseases. We therefore believe that an energetic educational campaign should be continued, but we do feel that the time has come when we can specialize in educational activities in relation to venereal disease more than we have in the past.

I have here some charts which I will show in a few minutes which will illustrate this idea of specialization in educational material for which we must devise certain methods to reach certain groups and have our educational material applicable to that group. Such a plan should increase the percentage of efficiency and reduce the loss of time and material that has undoubtedly occurred in some of the educational work carried on during the past four years.

In considering educational work for venereal disease control we should consider the relation of the educational system of the State to the health department in connection with an educational program among school children. A plan should be worked out by each State so that the various State educational departments will gradually make provision for meeting their responsibility in connection with training children of school age. The State board of health should cooperate in this plan with the educational authorities but should make it clear that ultimately each school system should meet its responsibility in connection with furnishing exhibit material and other facilities for a program of health education in the schools.

In connection with educational work I would like to refer briefly to the institutes and conferences of laywomen that we have had during the past year. Sixteen of the State boards of health have cooperated with the Public Health Service in conducting these public-health institutes. Only two of the institutes were specifically confined to venereal diseases; the others were on general public-health subjects. At these 16 institutes there were registered 1,718 physicians, 1,907 nurses and social workers, 238 students, 107 teachers and clergymen, 69 sanitary engineers, 46 judges and court officials, or an average registration of 391, the total registration being 6,254. The total number of clinics was 135, with a total attendance of 3,205.

We have reached very large audiences through these institutes which were attended not only by local people but by many who traveled considerable distances at their own expense. The registration at each institute is shown in the following table:

New Orleans, La	105	Minneapolis, Minn	142
Columbia, S. C	418	Portland, Oreg	180
Dallas, Tex	285	Kansas City, Kans	478
Birmingham, Ala	252	Spokane, Wash	140
Memphis, Tenn	299	Newark, N. J	589
Louisville, Ky	365	Albany, N. Y	137
Indianapolis, Ind	822	Hartford, Conn	777
Pittsburgh, Pa	264		
Chicago, Ill	1,001	Total	6, 254

In connection with several of these institutes, and in one or two instances as a separate event, there have been social hygiene conferences for lay women. The first of these conferences was held here in Washington last October, and was attended by 250 women. The next was held in St. Louis, Mo., in December last, and was attended by 400 women. These two conferences were not held in connection with institutes. The following conferences were held concurrently with the institute at the respective cities:

Columbia, S. C	250	Indianapolis, Ind	275
Birmingham, Ala	200	Pittsburgh, Pa	280
Memphis, Tenn	150	Kansas City, Kans	150
Louisville, Ky	270	Newark, N. J	500

The last institute was held in Newark, N. J., on April 19 and 20, and was attended by women who came from all over the State, and they came to this conference for the purpose of learning something in regard to social hygiene or venereal-disease control work.

Doctor Chesley pointed out to you yesterday that these women represent powerful organizations of a tremendous membership, and that they have shown an interest in this phase of public health work and have been a great help to various State boards of health. I cordially recommend that interest of these women be taken into consideration by each State department of health and that their aid be secured for extending the entire State program.

We had hoped to have Dr. Joseph S. Lawrence, director of the venereal-disease work in New York State, follow these remarks of mine by a brief presentation of the work in New York State. Unfortunately, however, Doctor Lawrence had to leave this morning, and is unable to participate in the program. He did, however, leave the charts which he intended to use in his address, and I am going to place these charts here so that anyone interested may examine them. You will find a chart which illustrates the idea of specializing in educational material, to which I referred a few minutes ago.

(As cuts of these charts are not to be printed, the last of Doctor Pierce's remarks will be eliminated, as he spoke entirely in reference to the New York State charts.)

Doctor CUMMING. We will now hear from you, Doctor Snow.

Doctor SNOW. I think it is a valuable report. It gives us a vision of what should be done in the future. I think that all the points which have been made are extremely practical, judging from what I hear of the people's viewpoint as I go about the country. We should do what can be done now to impress Congress with the importance of not cutting off the protective work which the board recommended. I understand the Department of Justice is ready to carry on this work if it is the will of the people that it should go forward. We can show that this is just a flying squadron of specially trained persons to gather accurate information in communities where there are troops, and to stimulate throughout the country similar local agencies for gathering information which given to the proper civil authorities induce them to act. This activity serves as a constant demonstration of what can be done not only in communities near military and naval posts but everywhere.

I hope the efforts of the interdepartmental board to have this work continued will be warmly supported by all of the health officers, because they are in a position to prevent confusion over the issue.

Doctor **Stiles**. It might be interesting for the health officers to know that they have a new convert to the venereal-disease campaign. A few weeks ago I had the pleasure of spending several days in a city of about 35,000 inhabitants. From information which I consider trustworthy, the Ku-Klux Klan in that city numbered 1,200 out of 35,000, and this same Ku-Klux Klan has taken up the venereal disease as part of its regular program. I did not know the Ku-Klux Klan had become interested in public health matters, but it seems to be a fact that in this city they have.

Doctor **Schereschewsky**. There is another topic which we might finish up. It has come into considerable prominence; and that is, the transportation of lepers. Doctor Kelley was to handle that. I will ask Doctor Chesley to say a few words.

TRANSPORTATION OF LEPERS.

Doctor **Chesley**. We are all very much encouraged in relation to the problem of leprosy in the United States. When Congress made an appropriation enabling the Surgeon General to take over the institution at Carville, La., and provide for medical treatment which promises arrest or cure in many cases—also to provide for transportation of cases to the sanatorium—they did a good thing. Several cases have been sent there from Minnesota. Others are willing and anxious to go, but are obliged to wait because of the lack of accommodation. Doubtless every State has a leprosy problem. The health officer may not know about all the cases, but as soon as the people concerned learn that there is a place to which patients may be sent without cost, where they will receive the very best treatment that is known under very comfortable and agreeable circumstances, both patients and their families will be equally desirous of taking advantage of it, and will let the health officer know where the cases are. Then without publicity the patients may be sent and treated if accommodations are provided at the sanatorium, and the leprosy problem will be solved. While leprosy here is a minor proposition, it is of great interest to the public, and, owing to the great injustice which may be done to the individual through lack of treatment and through actual persecution, it deserves consideration out of proportion to its real importance as a public-health problem.

Doctor SCHERESCHEWSKY. Is there any discussion?

Doctor McCORMACK. I would ask why it is not advisable to transfer the lepers to the leper sanatorium on ordinary trains and in an ordinary way. I do not believe it is necessary to unduly alarm people about the transference of these cases, and I think when a leprosy diagnosis is made they should be sent there with a nurse or somebody to go along and see that the ordinary precautions are taken. They should be sent immediately without any publicity; they have been traveling in this country for the last hundred years and have not increased the leprosy except by an importation, and I think we will decrease it by sending them to the leprosarium rapidly. It is an additional expense to send them in a private car, and I believe it gives the wrong idea anyhow.

A MEMBER. Has there been any recent ruling with regard to interstate transportation.

Doctor SCHERESCHEWSKY. The most recent statement in regard to that is contained in the revised interstate quarantine amendment. There has been no modification made in the amendment. In the case of a disease like leprosy you are dealing with a prejudice of the public. It will take some years to remove that fixed impresison of the public.

What Doctor McCormack advocates would be eminently desirable but would require education on the part of the public before they would consent to let you give ordinary transportation to a leper. Now they usually have a car to themselves. We try to get a tourist car and give them the whole car, and after that the popular prejudice is that the car company will have to renovate it. That is nonsensical, but that is a fact. They might as well scrap that car.

Doctor McCORMACK. I think that is absolutely absurd; the thing to do is to buy the fellow a ticket and send him down there, not saying anything about it. I think he ought to be shipped, and I think we ought to do it. I think we are rather excited and keep it going on, and I believe we ought to be spending the money that we spend for a private car for sensible things.

I think that statements should be given out through the radio system so the people will understand that leprosy transported is as little dangerous as any other disease. We should ship him like he has been traveling all the time.

We are finding some cases because we are really going after it. I would rather spend the money for buying those fellows something to eat instead of paying for tourist cars.

Doctor WELCH. There has not been a year in the last four or five years in which there has not been on the Gulf of Mexico an imported case of yellow fever. The health officers in whose jurisdiction that yellow fever occurred has notified all the State health officers immediately contiguous to him. In my case, when the notice came, I notified my governor that there was a case of yellow fever in a neighboring State, and that was the end of it. I have always told the newspaper reporters of the city of Montgomery and requested them not to put it in the papers, as there was no danger. I promised if there was any danger we would notify the public.

The last case which appeared on the Gulf coast died. The body was shipped to relatives in California.

I think we should teach the general public that there is no special cause for alarm in the transportation of lepers. I think we should teach them that there is no reason why those who are not lepers should be robbed of their good money to satisfy an unreasonable and unreasoning fear on the part of hysterical people.

Doctor **Stiles**. The present prejudice against leprosy is unquestionably due to the attitude of the Bible on leprosy. We are out of sympathy with that attitude, but we have to face the fact that the churches of the country have been preaching the terrible effect of leprosy from the year 1 down to the present time.

If the health authorities overcome that influence we are going to waste a lot of time. It is a good deal easier to do it in another way. Let us recall that a car carrying a case of leprosy might be interpreted as a life-saving device and might have free passage. It would be a simple matter to have a car, such as a laboratory car, as a life-saving device transport patients under the provision of the interstate law which gives to a life-saving device free transportation. That is a possible way out of it if it is a question of money, but as far as going against the present prejudice of the country, due undoubtedly to the pulpit and the Bible respecting leprosy, we are going to take hold of a great big piece of cake that we can't bite off.

Doctor **McCormack**. I believe every word the Bible says about it, literally and absolutely. I have as much prejudice in favor of the Bible as any man. All the same, I do not believe, in these United States of America, that the interpretation of the laws laid down handling leprosy in Palestine applies to modern conditions; and if we had unlimited funds it would still be wrong for us to waste a dollar in any such foolish proposition as paying for transportation of lepers in a private car. I think it is a matter of principle that we ought not to be guilty of the thing, and I do not believe that the churches and the pulpits would hesitate to agree to that. If we bought the lepers tickets and sent them, nobody would ever know it.

Doctor **Fulton**. I do not think the railroad company is entitled to notification of the moving of a leper. The way to move him is to move him. He will go through all right. Nobody will find it out.

The leper should not go unattended, but passengers do not have to know all about it.

Doctor Lumsden. Positive statements in regard to the degree of danger from association with lepers might be encouraging if we could be sure they were true. We do not know how the infection is spread. We do not know the period of incubation. So far as we know, years may elapse between the time of infection and the time of manifestation of the disease in some cases. In view of our state of ignorance about leprosy, I think that we as health officers would be subject to criticism if we advocated and put into practice the surreptitious transportation of lepers by common carriers. I doubt that any one of us here this morning would be willing to sleep under the same blankets that we knew a person with well developed leprosy had slept under the night before. I would not.

I think a thorough epidemiological study should be made of leprosy in the United States. We are finding more and more cases since the national leprosarium was established. They are coming to light. The disease appears to be spreading slowly but surely in some sections of this country. Recently, while on a visit to one of our small cities on the Gulf of Mexico, I had my attention called by the local health officer to a case of leprosy in a man who was living in a thickly built-up section. A number of men, women, and children were closely associated with that leper. Arrangements were made for the transportation of the man to the national leprosarium. Within the two weeks following, the local health officer discovered three other cases in that city. Two of the cases were in brothers who were attending a high school. Their father ran a restaurant and the boys worked in the restaurant from time to time. I think we should learn more about leprosy than we yet know before we sanction or advocate the transportation of lepers without reasonably rigid sanitary precautions.

Doctor Schereschewsky. The hour is now very late, and we want to get through. It seems that a motion to adjourn would be in order.

A Member. I move that we adjourn until 2.15.

(A recess was taken until 2.15 o'clock of the same day.)

AFTERNOON SESSION, MAY 18, 1922.

Doctor Schereschewsky. The meeting will be in order, pleas We still have one subject from the morning program before w pass to the general subject of child hygiene, and I think we shoul have a short discussion, and that is the question of uniform parol system.

Doctor Trotter has had a good deal of experience in that, and think it would be proper for him to say a few words before we g on to the subject of child hygiene.

Doctor TROTTER. In order that you may understand the parole system in force in Hawaii a statement of the arrangement between the United States Public Health Service and the Territorial board of health is necessary.

Kalihi Hospital is operated and maintained by the Territorial board of health, while the medical attendance is furnished by officers of the United States Public Health Service. In order to have free access to the clinical material available for research work an agreement was made by the United States Public Health Service and the Territorial board of health whereby the latter furnished suitable buildings for laboratory work and other purposes for the Public Health Bureau and allowed them the use of the hospital and all patients for research work on leprosy.

In other words the medical service is furnished by the United States Public Health Service while the administration and operation of the hospital is under a superintendent appointed by the board of health. This arrangement has been in effect for some years and has been satisfactory to all concerned.

The paroling of patients being a purely administrative measure, is under the authority of the board of health, though it is necessary for the Public Health Service officer in charge of the medical work to inform the board of health when any patients are considered fit for parole. There is no prescribed rule as to the length of time a patient must be held in the hospital before he is eligible for parole. The progress of the case must be such that the medical officer deems the patient able to return to his home without becoming a menace to the public. Under such conditions the medical officer reports to the board of health that such patients are fit subjects for parole. The president of the board of health then appoints a board of three physicians, who examine the patients, clinically (and bacteriologically if desired), and also their records while in the hospital. If a majority of the board find that, in their opinion, the patient can be paroled without being a menace to the public, they recommend that he be paroled, subject to certain conditions. The board of health at a regular meeting receives these recommendations of the parole board and puts into effect the recommendation of the board.

The conditions of the paroles are varied according to the conditions applicable to each case. All paroled patients are required to report to the hospital or to some representative of the board of health at intervals for observation. Many cases are required to report weekly, others monthly, some quarterly, and a few semiannually. After a period of a year or more the reporting period may be lengthened by the board of health in its discretion. After a period of years, usually four years or upward, if the patient has shown no evidence of active leprosy, application may be made to the board of health for a release from parole. A board of three physicians is appointed to reexamine the patient; and if found free of evidence of active disease, release is recommended and later granted by the board of health.

The board of health has come in for some criticism for paroling patients from Kalihi Hospital under the procedure as outlined above, as there have been a certain number of recurrences of the disease, with the result that some parolers have been readmitted to Kalihi Hospital, but in my opinion the paroling of these patients at this time was one of the best actions that the board of health has ever taken. This is because of the fact that the paroled patients returned to their homes on the various islands and were an object lesson to other persons residing in the district.

By reason of the paroling of such a number the board of health has gained the confidence of the people, and we are having patients come voluntarily and surrender themselves, and particularly so are parents sending in their children in the early stages of the disease, which is something that has never happened in the history of leprosy in Hawaii. We feel that having these children come in the early stages is most encouraging, for we believe that with the treatment now in use the disease can be arrested in them, and they can later return to their homes.

The Kalihi Hospital receiving station is on the outskirts of Honolulu, 10 minutes' automobile ride from the city. To-day we have, I think, 185 patients in this hospital. We have not made any transfers to Molokai since 1919. There is a 4-foot iron fence in front of it, and two employees guard it during the night to keep the buildings from burning down, but not to keep the patients in. That station is under a dual control. The attending physician is Doctor Hasseltine. He has charge of the medical work in connection with the station, while the routine administration is carried on by a most exceptional Hawaiian woman superintendent. She has been there for a little over three years, and in all that time the board of health has never received a complaint in connection with the institution, which I think is, considering the number of patients we have, a remarkable record.

So far as the medical treatment of the patients goes in the institution we leave that solely to the attending physician. We make no change at all in the treatment or any routine administration, except with his consent. It has worked out most satisfactorily, and we are grateful, indeed, to have a doctor of the ability, and one who has shown himself to take such an interest in the work, as has Doctor Hasseltine, of the United States Public Health Service.

Doctor SCHERESCHEWSKY. Is there any discussion on the subject?

Doctor GARRISON. I just want to get a little information. Some two or three weeks ago there was a case of a leper who came to Little Rock—a lady from a well-to-do family from Kansas City.

According to the history submitted to me, she had never been outside of the United States, had never been exposed to leprosy, and, according to a very good bacteriologist, the clinical diagnosis was confirmed. We immediately forwarded the blanks to the Surgeon General and requested the necessary transportation, etc., and asked for further instructions. I had not received any reply when I left home. The woman will abide by the regulations and go to a leprosarium. She prefers to be taken away in some other way if possible. As a matter of information, I would like to be informed what is the laboratory finding or clinical finding to warrant the control of a leper.

Doctor SCHERESCHEWSKY. Doctor McCoy, will you answer that question, on what would be the basis of allowing parole to a leper—the clinical and laboratory basis?

Doctor McCOY. The risk to the community depends largely on the geographical location. In Little Rock, or in the South generally, any case which is bacteriologically positive ought to be isolated. It is desirable, but not necessary, to isolate in an institution. Home isolation can be practiced with extremely small risk to the community.

The fact that the woman in question never was out of the United States does not have any particular bearing, since our Gulf coast is a recognized focus for the transmission of leprosy. In Florida and Louisiana practically all lepers are of local origin; in the North the reverse is true—that is, practically all are imported cases. One can unearth perhaps 50 cases of leprosy in New York at any time, but all these come from foreign countries or from the South. There is no appreciable risk of the transmission of the disease in a northern community.

This all has a bearing on the subject of uniform control. I doubt whether it would be wise to have a uniform system for the whole of the United States when the opportunities for communication of the disease differ in different parts of the country.

Furthermore, there are two clinical types of leprosy, one of which is practically free from risk of transmission. This is the anæsthetic or nerve type of the disease, and such cases are not a source of danger.

I want to conclude by adding my tribute to that of Doctor Trotter to the handling of leprosy in the Territory of Hawaii. I know of no community that has worked out a better program for the handling of leprosy than that little community in the middle of the Pacific Ocean.

Doctor GARRISON. Would it be feasible for the service to detail a man down there and advise whether it is better to let her stay home?

Doctor SCHERESCHEWSKY. It might be done, but I would have to take the matter up. Doctor McCoy might go down there. In the absence of the Surgeon General I can not make a promise, but we will give the matter consideration.

Doctor **Crumbine.** I will ask a question not appropriate to the matter under discussion, a question which has occurred to me a great many times, and I have never had an answer: Why is it that there are two places in the United States—Texas is one point; I think the other is in Charleston, S. C.—where absolutely no attention is paid to leprosy cases. They have perfect liberty. I do not know that it makes any difference what the type is. I assume there are both types. There is nothing done. There are 30 at Galveston that have liberty, and nothing has ever been done about it. I do not know how that is and why it is.

Doctor **Schereschewsky.** It is certainly the province of the State health authorities to take such precautions as are necessary for the protection of the people in the State. If these lepers attempt to cross the interstate boundaries, then they become proper subjects for Federal action, and under proper information steps could be taken to limit the activity. The trouble is that many lepers are unknown, and pass in the channels of interstate commerce without anybody knowing anything about it. I believe the establishment of the national leprosarium and the appropriate enlargement to take care of the leprosy cases helps wonderfully. Improvements which are pending in the treatment of leprosy, and epidemiological studies, such as Doctor Lumsden suggested to us this morning, will pave the way for a control of the situation, but the Chair is in accord with the health officers from Kansas and Iowa, that there is no reason why they should be free and unsegregated in the points referred to, and it ought not to be.

Doctor **Chesley.** I was requested to start the discussion, because I handed the Surgeon General a telegram, which was that we picked up another leper in Minnesota, who was a citizen of the Soviet Republic, and who desires to return. Personally, I am perfectly willing that it be done. I do not see why in these cases where you have difficulty you can not put your patient into a plane and fly him to the point where he desires to go. No interstate law can prevent us getting there. I think it is a simple thing.

Doctor **Schereschewsky.** That is a good suggestion.

The next subject is child hygiene, and I will ask Doctor Clark to open the discussion on that by giving us a short résumé.

CHILD HYGIENE.

Doctor **Clark.** When I outlined for you the activities of the child-hygiene section last year, a good deal of our work was in the formative stage. Now, some of the results of the work we were then doing have become apparent.

With regard to the scope of the work, I think the proposed slogan for health officers, " Investigate, demonstrate, and educate," applies particularly to the work of the service in child hygiene, with emphasis on " investigate " and " educate."

Owing to the terms under which appropriations become available for child-health work, our activities are largely confined to investigation. However, it is impossible at times to conduct an investigation and not at the same time demonstrate, or demonstrate without educating. It is a very important form of education—demonstration.

Morbidity reporting by the school medical service, nurses, or teachers.—In line with the discussion regarding the establishment of a morbidity registration area, it may be of interest to note that we are attempting to determine the value of morbidity reporting by the school authorities, as compared with reporting in other manner. We use for this purpose the special school record card adopted by the service which provides for a record of absences from school on account of sickness to be kept by the teacher or by the school nurse. The value of this method of reporting will depend very largely on the thoroughness of the cooperation of the school authorities with respect to recording absences and regular and prompt reporting to the health officer.

Aside from the value of this form of cooperative work in keeping the health officer advised of the prevalence of particular types of morbidity in the community, it is also possible by this method to estimate in terms of dollars and cents the loss to a community from the inability of children to attend school because of preventable sickness. We have recently compiled material of this character relating to 6,130 children in 13 Missouri localities which shows that of a total of 666,449 possible school days' attendance 5.6 per cent of these days were lost through sickness. In other words, at a per capita cost for schooling of $25 for each child, something like $2,500 was spent in these Missouri districts to no purpose. It is true this money is spent whether these children attend school or not, but the point remains that a number of children do not derive the maximum benefit from the educational opportunity thus provided because of preventable sickness.

The educational value of the economic data obtained in this manner is very great. The health officer will be in possession of definite information regarding the number of children who have been kept away from school on account of sickness and the amount of money spent in a given locality for school purposes without definite result. He will thus be in position to use this information to advantage in securing community support of public health work.

As indicated by an analysis of the material collected in these Missouri counties, "Sickness among school children," which appeared in the weekly Public Health Reports of June 8, 1921, it is possible for a health officer to keep himself informed by this method not only of the percentages of the different types of sickness prevailing in a community at a given time but also with regard to the seasonal prevalence of special diseases.

Further study of the practical application of this manner of morbidity reporting is now being carried on in a more scientific manner as a part of the child-hygiene contribution to the health demonstration work which is now being made in Hagerstown, Md., in cooperation with the Maryland State board of health and other agencies. Using the service school record form, teachers are keeping a very close track of absences from all causes. The teacher's reports are carefully checked, followed up into the homes by special investigators, and are finally referred to the family physician for confirmation of the diagnosis. The whole study is under very careful supervision, and when completed we feel that we shall have some very definite information regarding morbidity in this particular community and the value of this manner of obtaining morbidity reports. Personally I believe that if we can secure the intelligent and hearty cooperation of educational authorities wonders can be accomplished by this method.

The effect of the correction of physical defects on growth and development.—At the time of the last conference mention was made of the study under way in the city of Baltimore of the effect of physical handicaps on the growth and development of children. Originally 200 underweight children, suffering from two or more physical defects, attending schools located in the more congested districts of Baltimore, were selected with a view to having these defects corrected and measuring the effect thereof by comparing the results of periodic weighings made before and after correction. However, owing to a number of causes, but 146 children were under observation for a sufficient length of time for accurate statistical purposes.

The correction of these defects was made possible through the hearty cooperation of seven Baltimore hospitals. These children were given no instruction in hygiene and given no special attention while under observation, other than securing the correction of the physical defects. The reliability of the results is strengthened by the fact that during the period these children were under observation many of the parents were without employment because of the very general economic depression.

It is interesting to know that of the 146 children on the school register in June, 1921, 3 children advanced 1½ years in school work, 134 were promoted to usual school grade, and 9 failed of promotion.

Of these latter, 6 children were already over age for their grade in school. Of these 146 children on whom correction was made, 43 per cent were over age for their grade and had repeated from one to four years prior to the time the correction was made.

I have not the time to give you the complete analysis of the results of this study.

With regard to the rate of growth of the adenoid and tonsil cases, the monthly percentage gain in weight before the operation of the boys from 7 to 10 years of age was 0.4 per cent and of the girls 0.2 per cent. Following the operation the percentage gain for the boys was 1.8 per cent and for the girls 2.5 per cent.

In the 11 to 14 year old group the monthly percentage increase in weight for the boys was 0.47 per cent before operation and 2.04 per cent after the operation, while for the girls the percentage increase was 0.84 per cent before the operation and 1.99 per cent after the operation, respectively.

The expected increase in weight of children comprising the first group is 0.72 per cent for the boys and 0.79 per cent for the girls, and in the second group 0.83 per cent and 0.97 per cent, respectively.

It is thus seen that, as measured by gain in weight, the correction of this type of physical defect, although unaccompanied by any other measure for improving the child's physical condition, is attended by a very substantial improvement as measured by increase in weight. While this study, by reason of the limited number of children involved, may be considered in the light of a preliminary inquiry, the results warrant an extension of studies of this character in order that more definite information may be had regarding the effect of the corrections of certain types of physical defects on the growth and development of children.

Special studies in nutrition.—In connection with the widespread interest now manifested in problems relating to the nutrition of children and the more or less general acceptance of underweight as a measure of malnutrition, I wish to impress upon you that many factors are conducive to underweight, and considered alone underweight is not a true measure of malnutrition—that this condition is only a symptom and not a distinct pathological entity. For example, it is possible to fatten an infant by feeding for a more or less prolonged period on condensed milk, and yet fail to promote proper skeletal growth or increase its vital stamina.

We have but recently compiled data relating to the estimation of the state of nutrition by methods other than the weight-height index. These studies were made by officers of the United States Public Health Service in the case of 9,973 school children and show some very interesting results. In addition to weighing and measuring these children they were classified on inspection as of "excellent," "good," "fair," or "poor" nutrition. All of these officers were skilled in estimating the general physical condition on inspection by reason of the experience and training gained in the inspection of thousands of immigrants at Ellis Island.

In analyzing and comparing the results of these observations it was found that—

1. The percentage of defective nutrition classified according to clinical evidence other than weight was highest at 8 years of age and decreased with age. This observation lends support to the contention of some authorities that child development may be divided into distinct periods approximately as follows: The plump, chubby period, extending from early infancy up to the sixth year: the lean, lanky period, covering the seventh to the eleventh year of age; and finally the period of puberty, during which individual children manifest distinct characteristics that will persist through life.

2. The children classified as malnourished from clinical evidence other than height and weight are shorter, lighter, and have a lower weight-height index.

3. Differences in height are much less significant in judging nutrition than differences in weight.

4. In comparing percentage distribution of two groups classified as of "good" or "poor" nutrition, according to clinical evidence other than height and weight, it was found that although the children in the latter group weighed less than those in the former group some of the children in the poor group weighed more than some of the children in the good group. It is reasonable to assume, therefore, that weight measurements alone are not sufficient to determine nutrition, but that these must be supplemented by medical examination.

There is very great danger that large numbers of inexperienced workers will be misguided by their enthusiasm in using the easily applied and arbitrary underweight index and lose sight of the fact that malnutrition is a medical problem.

Follow-up work in the schools.—Those of us who have been engaged in school hygiene work are conscious of the need of some more effective means whereby better results may be obtained from the medical inspection of school children. It is an extremely difficult matter to secure the cooperation of parents for the correction of hampering physical defects. Notification is notoriously ineffective. Follow-up work in the homes by the school nurse is expensive, time consuming, and too frequently barren of results. In seeking a remedy the Public Health Service has devised a health score form for use in classrooms designed to take advantage of group psychology to stimulate the child himself to demand the correction of notified defects.

The system is simple. Certain minimum health essentials are set forth, with proper headings under which the results of the physical examinations are recorded. In every instance where the child is free from physical defect corresponding to any one of these headings a red star is stamped in the appropriate column. The child is then informed that following the correction of certain existing physical defects or the attainment of the minimum standard a blue star will be placed in the appropriate column, and when all the spaces are filled with red or blue stars, singly or in combination, a gold star will be placed before his name.

Our experience in the use of this form during the past year has impressed our officers and the school authorities with its value. In some communities a very high percentage of correction of defects has been obtained through the importunities of the child brought about by this manner even in cases where no follow-up work whatever had been done by the school nurse.

New work.—With regard to the new work undertaken by the child-hygiene section during the year, mention has already been made of the cooperative work being carried on at Hagerstown, Md.

In connection with certain studies relating to the prevalence of tuberculosis which the service is making in cooperation with the State Board of Health of Utah and the Utah Public Health Association, particular attention is being given to the related child-hygiene problems. Large numbers of school children are being examined, and those who are found in poor physical condition are referred to special examiners for attention. Personally, I feel that the period of childhood offers the most promising point of attack in the control of tuberculosis. It is practically impossible to diagnose incipient tuberculosis in children by any method. In fact, a special committee of the National Tuberculosis Association is on record as stating that even by the use of the X ray, unless the findings show involvement of the lung fields rather than the lung roots, the diagnosis of incipient tuberculosis can not be made in the child. For these reasons, a child presenting the combination of symptoms classified under malnutrition should be regarded as potentially tuberculous and the necessary means should be taken to improve his general condition. Child hygiene, by safeguarding the health of expectant mothers and assuring the unborn child a sound birthright; employing special means for reducing infant mortality and assuring better care, attention, and management of infants and children of preschool age; concerning itself with the improvement of school health supervision; and securing better provision for safeguarding the health of children engaged in industrial occupations is one of the most potent factors in the control of tuberculosis.

On request of the State and local health officers, the Public Health Service has been making special investigations in school hygiene in Bedford, Ind., and in Memphis, Tenn. The work at the latter place is too recent for me to give you the results of these studies at the present time.

In Bedford, Ind., however, our studies have developed some interesting information regarding the relationship of posture to malnutrition and also regarding the association of bad posture with physical defects. These investigations will be made the subject of special reports. In addition, the work of the service officer has been instrumental in bringing about the adoption of a system of health instruction in the public schools of the city which in itself, from the public-health standpoint, is ample compensation for the time and energy spent in these investigations.

The service has also been making some very extensive investigations of special child-hygiene problems in cooperation with the State board of health of Florida and the State federation of women's clubs. In order to secure material for special studies, the service has been obliged to do some extensive routine supervision work in the schools of two counties of the State. We have been particularly interested in collecting material for use in an attempt to prepare more accurate standards of physical development than those at present generally employed, and also for the purpose of studying the effect of certain physical defects and endemic diseases on school progress and the growth and development of children. The work is still under way and no definite information bearing on these points can be given at the present time. However, some very interesting side issues have developed as a result of our special studies which manifest the aroused interest of the local community in child health work. In one of the counties where we have been working better provision is being made for school health supervision, a number of nutrition clinics have been organized and operated, a child health center has been established to be operated by the committee of the local medical association on the withdrawal of Federal forces, and finally an arrangement has been perfected whereby the local dentists will give free dental attention to every necessitous child referred to them by the school authorities.

The activities of the service's mouth-hygiene unit have been largely confined to the State of Florida during the past year. In the counties where special studies of the effect of physical defects on the growth and development of children have been made the mouth-hygiene unit has examined, charted, and graded the mouths of the entire school population for use in determining the effect, if any, of bad mouth conditions on the child's physical growth.

As a result of the special investigations of the mouth hygiene unit, officers of the service are coming to a realization of the possibility that dental caries alone is not so much a factor to be considered in respect of the health and the school progress of the school child as is mouth sepsis evidenced by gingival infection and other inflammatory conditions of the oral tissues. According to these studies, a very interesting and strongly probable relationship between mouth sepsis and school progress seems to exist. In a very large number of instances, in fact apparently too large to be considered a mere coincidence, it has been found that for children with low mouth sepsis ratings, according to a method of grading devised by the unit, there is a corresponding low school rating, and vice versa.

In conclusion, I wish to say that I had hoped to make a few remarks regarding the organization of child health work on a State-wide basis, but I have already used up too much of the allotted time. In devising such a plan the health officer or the director of the division of child hygiene should make a comprehensive survey of his territory for the purpose of determining the most pressing child hygiene problems of the different communities, and to take stock of local resources, including the amount of cooperation that may be expected from auxiliary agencies. Our experience has been that, while a completed plan of child hygiene work is desirable, but few communities are in position financially or otherwise to put an all-embracing plan in operation. However, every community has one or more special problems which require special attention. The solution of such problem or problems should be the entering wedge, and as local resources increase the work may be gradually expanded.

Finally, I wish to emphasize that because of the interrelationship of all health problems any State-wide or local plan of child health supervision should provide for a very definite correlation of the child hygiene activities with the other activities of the State and local health department. Such correlation is advisable not only from the standpoint of economical expenditure of funds but it also promises the best results.

Doctor SCHERESCHEWSKY. The next subject on the program is the provision of the act of November 23, 1921, entitled "Promotion of the welfare and hygiene of maternity and infancy, and for other purposes," with special reference to detailed plans for carrying out the provisions of the act as specified in Section B in section 8.

We have with us to-day Miss Grace Abbott, the Chief of the Children's Bureau, and it is going to be our pleasure to have Miss Abbott address us on this most important topic.

I believe the recognition of the necessity for the protection of infancy in childhood by the Federal Government is of the most importance and a milestone in the progress of public health.

It gives me great pleasure to have Miss Abbott address you.

Doctor CUMMING. If Miss Abbott will allow me to make a short statement, I will appreciate it.

A friend of mine is in town, from Chicago, to help the Government in a voluntary way, a man who had done a great deal for the Government in the last year. He was suddenly taken sick about 12 o'clock, and General Dawes called me up about it. We have taken him to the Emergency Hospital, and they are about to operate on him, and while he was put under the anæsthetic I ran over here to apologize for not being with you this afternoon, and I am sure you understand it.

I hope we shall have the pleasure of meeting again next year and have a good meeting. I also hope that we shall have a very successful year in the following 12 months.

Before Miss Abbott has anything to say I want to say that we are working together in the utmost harmony, trying to carry out the intent with respect to maternity, and we hope it will result in a great deal of good.

PROMOTION OF THE WELFARE AND HYGIENE OF MATERNITY AND INFANCY.

Miss ABBOTT. I have not very much to say to you this afternoon, because I think we covered practically all the points that any of you wanted any information about on Monday afternoon.

It did occur to me, on thinking it over, that there was one thing I omitted to say. I did not report the progress with reference to the acceptance by the States of the Sheppard-Towner Act. Forty-two States have now accepted it, 11 by legislative acts, and the rest by the action of the governors, pending the next session of the legislatures. The plans of 33 States have been approved in final form, and we are hoping that the other plans will come in soon.

Doctor Cumming and Doctor Tigert, when he has been in town, have been very generous in giving the necessary time to the work of the board, so that we have been able to act on the plans promptly.

I am not able to say as yet that the comptroller is ready to pay over the first allotments. I hope, however, that all questions will be settled, so that this will soon be possible.

A great many of you have been discussing with us at the bureau your individual plans, and Doctor Rude and I appreciate very much having this opportunity of meeting and talking with you. We all have many problems, which I am sure will be solved in the years to come, and, unless there are some questions some of you would like to ask, I do not intend to say anything more now. I know you are already tired, and there will be more speeches this afternoon from persons whom you have not yet had an opportunity of hearing, and I am very glad to give way to them.

Doctor Schereschewsky. This subject is now open to discussion. If there is no discussion on this topic, we will proceed to the next topic, which is "Nutritional disease."

I will ask Doctor Goldberger to make some statements.

NUTRITIONAL DISEASE.

Doctor Goldberger. Mr. Chairman and members of the conference, I think some three or four years have passed without my attending these conferences and without making a report of progress. The main reason for this is that the progress of our investigations of pellagra was such that we did not feel prepared to report on them.

The results of the work of the past four years have confirmed the indications of our earlier results, which, as you know, pointed to the protein factor as the one concerned equally in the production and in the prevention of the disease. The indications are well-nigh conclusive that there is some fault bound up with the protein, in all probability with respect to the make-up of the amino-acid mixture, that is the essential factor concerned in the cause of the disease pellagra.

It hardly seems necessary to go into discussion of our recent results at this time, for they have already been dealt with in a report published in the Public Health Reports a few weeks ago (March 3, 1922). I may say, however, that additional confirmatory observations have been made of those there reported pointing to the protein factor as the essential one. Notwithstanding all this, we feel that there is still much to be done before it can be said that all possible dietary factors other than protein have been absolutely excluded from consideration.

Aside from their immediate bearing on the program of pellagra, the results of our studies have a broader significance. They suggest that a specific condition—a specific human disease—may result, so far as we can at present judge, from a defect in the protein factor alone.

Doctor Schereschewsky. Is there any discussion of Doctor Goldberger's talk? If not, the recent outbreaks of virulent smallpox in certain sections of our country and the fact that vaccination is not being practiced with the assiduity with which it should be practiced in a number of sections of the country render some discussion of certain features of the vaccination against smallpox pertinent at this time, and I will ask Doctor Leake to open the discussion in this matter.

VACCINATION AGAINST SMALLPOX.

Doctor Leake. Gentlemen, the hour is late; there are a few points that I think may not be generally appreciated, and I want to touch upon those only.

The chairman referred to the virulent outbreak in the two Kansas Cities; the infection has spread from there to other places, notably Denver.

The form of the disease which is prevalent there is the old text-book form, our milder American smallpox being a less virulent form rather than a separate disease. The smallpox in Kansas City was a type which had a mortality of from 30 to 40 per cent. There is one point in that outbreak which seems to be true of other severe outbreaks, and which deserves to be mentioned—the contagiousness of the disease under these conditions. Apparently it is more contagious, as well as more fatal, so that more severe measures have to be taken in isolation; further, in regard to vaccination, one can not be sure of an old vaccination protecting to the same degree as it does against our milder form. In Kansas City we found a few cases in this epidemic that were vaccinated as recently as three years ago, with perfectly good scars. These cases tend to be somewhat milder, of course. None of those who were vaccinated two to two and a half years ago had fatal cases, but it would seem that to promise immunity one should ask for revaccination in the presence of such a contagious outbreak unless one has been vaccinated within two years.

Furthermore, vaccination during the early part of the incubation period did not prevent the disease. The vaccination should be performed before exposure. We can not hope to do all the good we can unless we get our communities vaccinated earlier.

Everyone knows that we would like uniform vaccination at school age. It is appreciated that this can not be had in certain communities. The population will not stand for it. In some communities, in the most populous ones, school vaccination is in vogue; we hope that it always will be, and that there will be no stepping back from as much protection as we have.

In Sweden recently the vaccination laws have been amended so as to adopt the American plan of vaccination at school age, instead of the usual European method of vaccinating in infancy. If only one of the two were to be selected, the American method is better. Certainly the English idea of one vaccination giving perfect protection, provided there are four good-sized scars, covering a square inch, can not be held entirely sound—it probably is a good method, but any infantile vaccination will gradually lose its protective power in a considerable proportion of individuals. If we had one time to choose it would be the school age, as this would probably give the more lasting immunity. Two advantages of vaccination in infancy are, there is usually no fever, and the scar tends to fade.

One minor point in regard to the apparent failure of vaccination in such an epidemic as we had in Kansas City; a few cases were seen where, according to the description at the hospital, the patient had a good vaccination and still came down with smallpox, the facts being as follows:

Vaccine virus was inserted on the arm, but no exact record had been kept of the date of insertion and the date of the appearance of the vaccinal reaction; the sequence of events was learned only on questioning the patient and using a calendar to help him fix dates. The vaccine virus was not potent and lay dormant in the skin; instead of coming up to a maximum "take" in 9 to 11 days, it showed no signs of "taking." The patient was exposed to smallpox and the smallpox fever came on in 12 days after exposure, the virulence of the infection stirred up the attempted vaccination so that this became the first site of the smallpox eruption and came out a day or two before the general eruption. It was not the failure of vaccination to protect, but failure to get a vaccination.

In regard to the so-called "alastrim": In this country there is no trouble, except in individual cases, with the diagnosis of mild smallpox. The epidemic itself is easily diagnosed. There is no reason for regarding the alastrim of the West Indies as anything different from our mild smallpox. It is the same disease. The fact that there are few or no deaths has nothing to do with the way it should be handled. The other features of alastrim are present in our epidemics of smallpox.

In regard to the so-called reactions of immunity, the reactions which take place on the arm when a person has already been protected by previous vaccination, there seems to have been some question as to how these appear and what the absence or presence of the reaction means. If a person is vaccinated with a potent vaccine, there is always some reaction. In cases with no previous immunity there is the regular primary vaccinal efflorescence, with the maximum at about 9 days, practically nothing during the first 2 or 3 days, and the widest extent of redness at the 9 or 11 day period. If a person has a slight amount of immunity, the reaction will begin a day or two sooner and come up to its maximum around the seventh day, the total area not being so great as in a primary "take," although on the seventh day you may notice a higher reaction than in the case of the corresponding primary vaccination at that day. The reaction of immunity, occurring in those who are moderately to highly immune, is a briefer affair, the reaction coming up ordinarily with a person who has not been vaccinated in three or four years, so that it reaches its maximum about 48 hours after inoculation. A reaction in one of these three forms will take place with practically every person who is vaccinated with vaccine, and this reaction can have a maximum at any point within 10 or 11 days; commonly anything in the first 3 days is called an immune reaction; anything from

3 to 8 days an accelerated reaction, and from then on a regul
vaccinia.

The early reactions generally indicating immunity can take pla
with dead virus, but active virus is necessary to get the proper int
pretation of the reaction.

Doctor SCHERESCHEWSKY. We will now hear from you, Doct
Beatty.

Doctor BEATTY. I am not proud of the fact, but Utah can cla
the distinction of having had the highest smallpox rate in the Unit
States every year for the past 20 years. There is a reason. I mig
say 22 years to be more exact, because it was at that time that t
State legislature passed a law expressly prohibiting health autho
ties or school authorities from excluding unvaccinated pupils fr
school or requiring the vaccination of any individual in the co
munity.

I think the facts are rather interesting from an epidemiologi
standpoint, worthy perhaps of careful study, because they can
be duplicated elsewhere.

I need not go into the causes leading to the enactment of the fre
law other than to say that it was a result of fanatical antivacci
tion activities in high places. The result of the law and adve
public sentiment responsible for it has been a largely unprotect
population. I can not recall a year in which smallpox has not be
prevalent, assuming epidemic proportions in many years. In 19
there were 5,000 cases, and 1921 more than 3,700; the population
the State is 450,000.

The presence of the malignant type of smallpox in Kansas Ci
Denver, and other western cities last winter, however, has had
tremendous influence in changing the sentiment and stimulating va
cination, and there is reason to believe that the repeal of the an
vaccination law may be accomplished at the next session of t
legislature.

Doctor TURNER. I just want to take a minute to tell you a lit
of the situation in the State of Washington. I do not want to fig
with Doctor Beatty in saying that we have more smallpox in t
State of Washington than in any other State in the United Stat
but I believe we come pretty near having the most, or we did ha
some years ago.

Last year, in July, the State board of health passed a regulati
in order to control smallpox to the best of our ability, so we pr
ceeded to put this rule into effect, and immediately ran into all so
of difficulties and the usual fights to get the procedure over.

It went to the court in Thurston County. We received a decisi
and they appealed to the supreme court. I do not care to take
the time to tell you the whole situation. I merely want to read t

cision we obtained of the supreme court, and it is so good that really stopped thinking about passing any laws on public health the State of Washington. It makes it a regulation so flexible that are pretty well off, I think. This is a part of this decision:

> The statute declared the act of the board of health to be final and con- sive, and not to be reviewed by the courts or denied, because the authority y be abused, or the law maladministered, and that the finding of facts by perly constituted health officers is final and binding upon the public school d upon the courts.

There seems to be nothing further which needs to be said.

Doctor SCHERESCHEWSKY. We will suspend the program for a minutes until we receive the report of the resolutions committee.

REPORT OF RESOLUTIONS COMMITTEE.

Doctor DALTON. Mr. Chairman, the following resolutions have en presented to the resolutions committee, which have been passed on by them.

The first was read, as follows:

> Whereas a considerable number of cases of leprosy are known to State alth authorities and nearly all of these cases are living at their homes or e being cared for elsewhere under conditions unfavorable to treatment of e disease even if favorable to protection of the public; and
>
> Whereas the Congress of the United States has enabled the Public Health rvice to take charge of and enlarge the institution at Carville, La., so that limited number of cases have been admitted from several States and now e being given the best possible medical treatment under very happy and mfortable conditions of living and of environment which give great promise f arrest if not complete cure of the disease; and
>
> Whereas many unfortunate sufferers who have learned of this institution w, its advantages and being desirous of obtaining treatment therein find at the accomodations are so limited that no hope seems to remain of pos- ble relief or cure in their cases: Therefore be it
>
> *Resolved*, That the State and Territorial health authorities here assembled official conference with the Surgeon General of the United States Public alth Service respectfully petition the Congress of the United States to ap- propriate a sum of money sufficient in the opinion of the Surgeon General to large the Carville institution and provide ample facilities for care and eatment of all cases of leprosy referred by the State health authorities.

The resolution was adopted.

Doctor Dalton thereupon read a resolution which was adopted in the following form:

> Whereas the conference of State and Provincial Health Authorities of North merica have gone on record that changes in the sanitary railroad code are t advisable annually, but that the same be made not more frequently than five-year periods, or when necessary, and has instructed the committee to accordingly: Therefore be it
>
> *Resolved*, That the Surgeon General of the United States Public Health rvice appoint a committee on railway sanitation, and that this committee

On request of the State and local health officers, the Public Health Service has been making special investigations in school hygiene in Bedford, Ind., and in Memphis, Tenn. The work at the latter place is too recent for me to give you the results of these studies at the present time.

In Bedford, Ind., however, our studies have developed some interesting information regarding the relationship of posture to malnutrition and also regarding the association of bad posture with physical defects. These investigations will be made the subject of special reports. In addition, the work of the service officer has been instrumental in bringing about the adoption of a system of health instruction in the public schools of the city which in itself, from the public-health standpoint, is ample compensation for the time and energy spent in these investigations.

The service has also been making some very extensive investigations of special child-hygiene problems in cooperation with the State board of health of Florida and the State federation of women's clubs. In order to secure material for special studies, the service has been obliged to do some extensive routine supervision work in the schools of two counties of the State. We have been particularly interested in collecting material for use in an attempt to prepare more accurate standards of physical development than those at present generally employed, and also for the purpose of studying the effect of certain physical defects and endemic diseases on school progress and the growth and development of children. The work is still under way and no definite information bearing on these points can be given at the present time. However, some very interesting side issues have developed as a result of our special studies which manifest the aroused interest of the local community in child health work. In one of the counties where we have been working better provision is being made for school health supervision, a number of nutrition clinics have been organized and operated, a child health center has been established to be operated by the committee of the local medical association on the withdrawal of Federal forces, and finally an arrangement has been perfected whereby the local dentists will give free dental attention to every necessitous child referred to them by the school authorities.

The activities of the service's mouth-hygiene unit have been largely confined to the State of Florida during the past year. In the counties where special studies of the effect of physical defects on the growth and development of children have been made the mouth-hygiene unit has examined, charted, and graded the mouths of the entire school population for use in determining the effect, if any, of bad mouth conditions on the child's physical growth.

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tance and a milestone in the progress of public health.

A MEMBER. The question arises in my mind as to how you ar going to help yourself. When a town has a limited amount o money, and has bonded itself to the limit. and has not a good wate supply, they must have fire protection.

Doctor SCHERESCHEWSKY. This resolution does no more than minimize these conditions; and if this matter is placed under the jurisdiction of the board of health it would have records which do no exist now within the knowledge of the board of health, by-passe and all connections, and some supervision can be maintained ove them. I realize the practical difficulty in the rigid enforcement o this.

Doctor CHESLEY. In Minnesota we have had several epidemics due to physical connections for fire purposes. The emergency occurred, and they turned it into the water supply. The damage was done before anybody knew about it. We have found in places where they are putting in new supplies, and needed a supplemental supply for emergency purposes, the influence of the insurance companies was against making any provision for the protection of the public in such an emergency. It is possible through such mediums, which would vary under different conditions, to protect the supply, even if you have to take it in emergencies. That is what we are trying to do. We should not arouse the opposition of the fire underwriters and other commercial organizations when we attempt to safeguard the water supply against possibilities of pollutions. That is the whole intent of the resolution—to gain their cooperation and limit the active opposition which very often prevents getting something like that done until after an epidemic occurs.

The resolution was adopted.

Dr. SCHERESCHEWSKY. Now the question is as to adopting the report of the resolutions committee as a whole.

A MEMBER. I move its adoption as a whole.

Doctor SCHERESCHEWSKY It is moved and seconded that the report of the resolutions committee be adopted as a whole. All in favor will signify the same in the usual manner.

(Report of resolutions committee adopted as a whole.)

We will resume the program. The next topic is the question of industrial hygiene. In view of the growing importance of this phase of public health, I will ask Doctor Thompson to discuss this.

(Doctor Thompson thereupon read the following paper:)

INDUSTRIAL HYGIENE.

In opening the discussion on industrial hygiene I would like to remind you of several facts. In the past several years students of epidemiology and State and local health authorities have begun to take notice of the importance of those diseases represented by heart disease and Bright's disease which are becoming each year a more and more important factor in the general death rate. Our interest is naturally not so much with the disease itself as with the underlying causes which contribute to the disease. It is true, of course, that a part of the apparent increase in the mortality rates from these diseases is due to the decreased mortality in communicable diseases, such as tuberculosis and typhoid fever, but nevertheless any disease which represents to us the beginning of the impairment of the physical machine can not fail to attract and hold our undivided interest.

The field of preventive medicine that State health officers have been interested in in the past has been so broad, with perhaps the funds for the work so small, that industrial hygiene and sanitation has received but little consideration. This is evidenced, I think, by the fact that the majority of States have either very incomplete industrial laws or none at all, and the divisions of industrial hygiene are to be found mainly in State departments of labor rather than State health departments. In my own mind it is quite clear that with the realization of the importance and the necessity for studying the causes of organic diseases such as I have referred to, the relative importance of industrial hygiene and sanitation will stand out with increasing significance.

Every physician is acquainted with the symptoms and effects of lead poisoning, and this class of poisoning has probably been more completely studied than any of the toxic metals. The result is that it has been definitely proven that permanent degenerative changes take place in excretory, circulatory, gastrointestinal, and nervous systems. Thompson, in his work on occupational diseases, states that more than 150 different trades subject the workmen to plumbism. The extremely wide variety of these trades, including as they do mining and smelting, painting, pottery, glass industries, shipbuilding, paper making, and others, makes it evident that in every community we will find the hazard and that the number of people exposed to this single poison is extremely large. While the actual number of cases of lead poisoning that are found may not be startling, on the other hand there are thousands of workers who have received a permanent physical handicap they must carry through life, no matter what their future occupation.

I have taken lead as only one example of a group of hazards, and in a great majority of work processes health hazards of the same sort exist. It is my own opinion that the State health officials in the near future will be compelled to recognize the importance of the industrial life of their communities if they expect to make any great impression on their present death rates.

The program of the Public Health Service in industrial hygiene and sanitation may be taken up under four main divisions:

First. Scientific investigation as to the cause, effect, and prevention of the more important health hazards, especially the principles of ventilation, illumination, and industrial sanitation, in order to make data available to State and local authorities for use in the formation and standardization of their industrial codes.

Second. A study of industrial sickness or morbidity records to determine the nature of such illnesses and the relative importance of various industrial health hazards in their causation.

Third. The maintenance of a consulting service for the benefit of industry, the individual employer, and State and local health authorities where questions regarding industrial hygiene and sanitation can be answered from the available literature on the subject.

Fourth. The introduction of the principles of industrial hygiene and sanitation into Federal business to eliminate the known health hazards that exist in the many divisions of work now being carried on by the Government.

Doctor SCHERESCHEWSKY. The subject of industrial hygiene is now open for discussion. I realize all the State health officers have been actively employed in the problems of the protection ot the public from the diseases which kill so many, but inasmuch as I know it is the aim of all of us to round out our health activities to the fullest possible extent, it seems to me in the future at least more thought must be given to the active measures in regard to industrial hygiene, for by so doing we protect the health of a group of individuals which is somewhere in the neighborhood of twenty-five or thirty millions.

Is there any discussion of Doctor Thompson's paper?

As most of you are aware, we recently had here a conference on the education of sanitarians, and as a result of that a committee was appointed. I will ask Doctor McLaughlin to make some statements as to the status of the work.

EDUCATION OF SANITARIANS.

Doctor McLaughlin. I know you are all tired, and I will take but two minutes.

The question of education of sanitarians is of deep interest to us, because the carrying out of the education of sanitary officers depends upon the cooperation of the health officers on the one side and the educators on the other. I am speaking because of misunderstandings that have occurred.

In the first place, if we had invited this conference and had present the health officers like you and like me in sufficient numbers, the shrinking violets of deans of medical schools and university presidents would have sat back, and we would have gotten no opinion from them—for that reason we failed to feature the practical health officer like you and me. We had a marvelous conference, so far as the attendance of these shrinking violets of educators is concerned, and we got them here and explained the problem to them. Another criticism that was made was that the newer phases of public health, such as child hygiene, were discussed and presented in half-hour papers, which is absurd; but we had no thought in mind of giving them a complete education.

We made an outstanding picture of each particular phase of child hygiene so that they would know, and know in some instances for the first time, that these phases were a necessary part of the education of the health officers and of the education of the raw material from which health officers are produced.

Another criticism that was made was this: That the conference contemplated the education of the ideal health officer who must know everything about everything. The only answer to that is, while a large part of the conference was devoted to the health officer of the future, the one we would like to have, and it was thought wise to look into the future to that extent, we all realized that the big problem to-day is the training of the sanitarians now employed, and the education of the raw material that we will be compelled to utilize for the next generation, regardless of any special schools of public health that may be established.

The result has been mailed to you, and a committee was appointed to follow it up to bring about the improvements in the education of the health officers. This committee in its work put a large part of its effort on the education of the health officers now employed, and the type of material we have to employ, and out of that the practical side will be taken care of, as well as the ideal side—what Doctor Vincent called, in his inimitable way, the education of the superman.

I make this explanation so you will understand we had no such thought in mind. Doctor Garrison and Doctor Chesley and myself, who received our education in the university of hard knocks, would be the last to belittle that type of education which succeeded so well; but we thought it would be well to look to the future, so that the kind of men we would like to see with the kind of training it took 20 years to get, might be produced in a much shorter time.

Doctor **Schereschewsky**. Is there any discussion of Doctor McLaughlin's progress report?

We have on the program the immigration problem. It is a big problem, and has had a powerful effect on the complexion of this country. I will ask Doctor Kerr to open the discussion on the matter.

Doctor **Kerr**. Gentlemen, I feel that I can bring in no concrete suggestion or recommendation to you regarding the problem of immigration at this time. I assume the secretary of the conference called on me by reason of my recent association with these problems at Ellis Island. I was in charge of the medical work there for three years. Anyone who has been there and has been associated with problems of the groups of people who have come to this country must be impressed with the enormous importance of immigration. The migration problem is probably one of the greatest factors, and has been through thousands of years, in changing the character and destiny of nations.

Perhaps the best example of the effect of immigration may be seen in the valley of the Danube and the Balkans, through which western migrations have traveled for 1,500 years. There is no section of the world that I know of that shows as well the ill effects of these world movements.

Our immigration problem relates, first, to the future of the race; and, secondly, to the immediate effect of arriving aliens on the public health.

The States on the Atlantic seaboard are confronted with these problems to a greater extent than the Central States. By reason of the examination of large groups of men who went into the Army we were impressed with the influence of certain groups upon the physical status of our population more than otherwise would have been the case. Statistics on the examination for the draft show that the stature of the recruit on the Atlantic seaboard was less than in the Central States, and this characteristic is attributable in a large measure to the accretion to our population. In those States where the immigrants have settled and the alien population is large health officers should give careful attention to their presence in the general population and endeavor to carry on work especially for them.

Last year at the conference I referred to the attention that was paid to the education of children while they remained at Ellis Island. That, of course, is the very beginning of a large social obligation on the part of this country. It has helped that phase of the immigrant's life.

I would like to impress upon the members of the conference that there is no movement going on in this country that so vitally affects the future of the country as the problem of immigration. We are now, with the very reduced immigration, getting almost a half million people into this country a year. Formerly they came over in millions—over a million a year. It is utterly impossible for the American population, as large as it is, and as open-armed as it has been, to assimilate such vast numbers, and those of us who have been in close touch with it feel what a great problem it is.

From a race standpoint we do not know what it means. We know perfectly well that if we were going to breed a better line of horses we would not go down to Central America and bring mongrel ponies here. We would go to Europe and get the best stock we could find.

There are many, many sources of immigration in Europe—people who would be glad to come—those that we can assimilate—and it is that class of the population that should be encouraged and the other class should be discouraged. The sick and disabled, those suffering from excludable diseases, should be kept out of the country. We have not been so fortunate in this respect as we should be. There have been cases landed in this country who are excludable under the law, and by reason of the conditions of war they were not returned. They left with us seeds here and there of defective stock. I do not know that there is anything this conference can do with respect to these matters. It is a Federal problem; but if the conference and those interested felt that the people of the country realized the problem that confronts them and could support their hands, I dare say our laws would be more stringent, and we would be assured of their better enforcement.

Doctor SCHERESCHEWSKY. Is there any discussion? If not, we will take up the last subject on the program, "Rabies eradication by vaccination of dogs."

RABIES ERADICATION BY VACCINATION OF DOGS.

Doctor STIMSON. Mr. Chairman and members of the conference, a little over a year ago three Japanese investigators reported that they had a method for immunizing dogs against rabies. They supported this by laboratory experiments and tried it out on a large scale. Some 15,000 dogs were immunized. These were pet animals, and up to the length of the period of observation they reported that not a case of rabies had appeared among these immunized animals.

At least one manufacturer of biologic products in the country took up this matter experimentally to begin with, and the experiments indicate that the findings of the Japanese can be supported. They have already put on the market a preparation which can be used and is being used by owners of valuable pet animals.

Now, the question I would like to put to the conference is, Is it possible that this method may be employed for the widespread immunization of the dog population and may it prove a valuable weapon in the suppression of rabies? In some areas the losses from rabies are very considerable. The principal loss, of course, is live stock. The second loss, I suspect, in actual money value is in the amount which must be expended for the treatment of exposed persons. The third loss is the actual loss of life computed in dollars and cents. This is a relatively small item, because the Pasteur treatment is usually successful. I suppose that a good many States are expending a good deal of money in measures intended to in some way combat rabies, but these methods, I think, are usually ineffectual, except that they do limit the number of human deaths.

It occurs to me that if the contention of the Japanese investigators is correct, that by a single injection of this preparation a dog can be almost permanently immunized, there may be the means of fighting the disease which will prove economical and practical.

I would like to leave the question with the members of the conference to see whether in their own States, granted the method is practicable from a purely scientific standpoint, it would save them money and add to their prestige in getting rid of a disease, or be a practical thing to put into operation. At the present time, of course, all States, or I suppose many of them at least, have regulations regarding the licensing of dogs. I suppose they are very commonly evaded. In country districts you will find five dogs on a farm and none licensed at all.

Suppose it were possible to drive up to a farmhouse, to go to the farmer and say, "Have you ever lost any stock from hydrophobia or rabies?" I think in many cases you would get a positive reply. In some places you could hardly go to any farmhouse without getting a positive reply. If you could say to this man, "We have in the wagon some stuff that will immunize your dogs; they will not have rabies any more, and at the same time we are willing to indicate that these dogs are protected by putting a tag on them," I think such a proposition might meet with success. Heretofore I have heard it said that if you went into a country district and tried to round up dogs, and tried to make people pay their license, and put a tag on them, you had to send an army along with the inspector to protect him. Otherwise he would be shot within a few miles. That statement was made to me by an inspector of a State live-stock board. I think that is practical, but I would like to leave it to the conference.

The work of the Japanese seems to be good. We have not done any experimental work with it as yet, and I do not think it is worth while doing, unless the State health officers report to us it would be a practical method, provided it was confirmed that you could immunize dogs in this manner.

Doctor WELCH. How many doses do you have to give to a dog?

Doctor STIMSON. One.

Doctor SCHERESCHEWSKY. Is there any discussion?

Doctor BEATTY. Early in 1917 rabies entered Utah, never having been known to have existed there before. It had been introduced in southern California some years earlier, spreading through the State into the other Pacific States and by way of Nevada into Utah. Much damage had been experienced and the prevalence of the disease was very extensive.

A conference was called by the Surgeon General in Salt Lake City, attended by State health officials of Pacific and intermountain States to consider ways and means of prevention. It was recognized that a difficult and unusual problem was presented by the fact that coyotes and other predatory animals were numerous throughout the region and that measures looking to their destruction were essential.

Following the conference the United States Biological Survey joined forces with the State and an effective campaign against predatory animals has since been waged with considerable success. The attempt to enforce the muzzling of dogs has proved ineffective, partly because of the lack of public sentiment notwithstanding the very large loss of live stock, and the fact that more than 150 people in Utah have been bitten by rabid animals. There have been three fatalities, only one of whom had received antirabic treatment, and we are unable to vouch for the administration in this case, as it was not given by the board of health.

With the exception of a very few cases the treatment was administered by the board, for the greater part using material furnished by the United States Public Health Service. Doctor McCoy may be interested to know that in one of the exceptional cases, where the material was sent to an outside doctor, the entire first half of the treatment was given at one dose without apparent ill effect. In another case the glycerine in the bottles instead of the sections of cord was injected.

The prophylactic inoculation of dogs appeals to me; but what are we going to do about the coyotes which continue to be our worst problem?

Doctor **STILES**. The suggestion is particularly opportune at this time. The live-stock industries of the country are thoroughly awakened to the importance of the dog in the transmission of diseases.

Doctor **WELCH**. The Georgia State Board of Health some two years ago made a survey of the country and issued a statement to the effect that rabies was more prevalent in Virginia, North Carolina, South Carolina, Tennessee, Georgia, Florida, Alabama, and Mississippi than in all the balance of the United States.

It is a very serious problem in the State of Alabama and the South, and if it is possible to vaccinate the dogs against it we can solve the problem.

I am very sorry that I have strapped up my charts, because I have a very graphic outline on the work which has been done in Alabama. I will say to Doctor Beatty that it does not make any difference how well you treat them, a few of them are going to die. We lose on an average 1 in 900. We treated as many as 1,800 parties bitten without a death, and then lost 2 right together. Our average is 1 in 900 people treated. We treated anywhere from three to four hundred a year, and we have lost during that time since the establishment of the Pasteur Institute five or six—I have forgotten the exact number—and during that time there have been 22 people in Alabama who died who were not treated. The theory is if the tooth of the dog penetrates a nerve sheath the man is going to die. All the cases that we have lost have been bitten about the face or hands. In every case that comes to us bitten in the face we push the dose to the verge of tolerance, but even then we lose the majority of them. We are more fortunate when they are bitten about the hands, but wherever they are bitten about the fingers or on an exposed surface we push the dose to the verge of tolerance.

If it is possible to immunize dogs, it seems to me the problem has been solved. It should not be difficult to obtain laws compelling the immunization of the dog population. I would like to see the United States Public Health Service prove beyond question the truth of this proposition.

Doctor **GARRISON**. May I ask the name of the biologic house that is putting out that preparation?

Doctor **MCCORMACK**. Lederle; and it passes through the Bureau of Animal Industry.

Doctor WELCH. It is standardized, is it?

Doctor McCORMACK. It is standardized.

Doctor SCHERESCHEWSKY. Is there any further discussion? If not, I will ask Doctor Stimson to close.

Doctor STIMSON. I am glad the subject of coyotes was mentioned, because I suppose there are comparatively few people bitten directly by coyotes. They are bitten by dogs, which in turn were bitten by coyotes. If dogs were immunized they would not have become rabid and the bites would not have caused rabies.

Doctor WELSH. Where do you introduce the virus?

Doctor STIMSON. Under the skin; it is subcutaneous.

There is one thing I did not mention, and that is that in any campaign against rabies there have got to be taken into account the wandering and ownerless dogs; but how are you going to tell the wandering and ownerless dogs? They used to send out and kill all wandering dogs having no collar on or evidence of the owner, but in some sections of the country it is not practical to do that, and in others it is not safe.

It is possible, if the immunized dog could be identified by some sort of fairly conspicuous tag, showing he was immunized, it would render the problem of dealing with ownerless dogs a little easier, because after this campaign is pushed through the country to get people to immunize their dogs, and they have been told about it, you would have greater justification for killing off the wandering population of dogs, which will be a menace until it is controlled.

Doctor SCHERESCHEWSKY. Is there any further discussion? If not, I declare this twentieth annual conference of the State and Territorial Health Officers of the United States Public Health Service is concluded.

The Chair speaks for the Surgeon General, who is unavoidably absent, and thanks you for your attention, and hopes this conference will be as productive of valuable results as the conferences have been in the past.

A motion to adjourn will be in order.

(A motion was made to adjourn, which was duly seconded and carried, and the conference of the State and Territorial Health Officers with the United States Public Health Service adjourned at 5 o'clock.)

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COMMUNICABLE DISEASES AND TRAVEL

By

THOMAS R. CROWDER, M. D.

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Successful disease control depends largely on education of the public, and particularly on the education of those who have the direction of the traveling public. Doctor Crowder's work will be of great assistance in that education.

VICTOR G. HEISER,
Surgeon, United States Public Health Service.

NOVEMBER 6, 1922.

COMMUNICABLE DISEASES AND TRAVEL.

THE COMMUNICABLE DISEASES.

Communicable diseases are of many kinds, but they have some things in common: They are all caused by living organisms growing as parasites in the bodies of affected persons; they are transmitted only by a material transfer of the causative organism, which must be still alive and virulent; and each case comes from a previous case of the same kind. An epidemic or an outbreak is only a continuing chain of infection. In a few diseases only it may pass from animals to man; but most of the communicable diseases of man are peculiar to man alone, and if we could make impossible any transfer of the causative organisms from infected to well persons, the infecting chains could not be formed and the infection could not go on.

These facts are fundamental to communicable disease control. The sanitarian tries to destroy the links of the connecting chains of infection. In order to succeed, he must know where the origin is and how the links are formed. In some of the communicable diseases we know in great detail just where the contacts lie and how the infection passes. There may be only a single way of linking one case with another, as through the bite of an insect, in which case the means of prevention are clear. In others, while we know the causative organism, where it exists in the body, and how it is shed off, there are a multitude of possible routes by which it may reach a second person, and prevention is correspondingly complex and difficult. In others still, there are many obscurities; for neither the causative organism nor the ways of its transference have been accurately determined, and we can deal with them only by their analogies to diseases which are better known. Many times these analogies are so clear as to leave little doubt of the general facts concerning transmission, but there will always remain some uncertainty until further studies have given us more definite knowledge.

METHODS OF TRANSMISSION.

Everyone is familiar with the old belief that diseases are contracted from filth, foul air, effluvia, and the miasmas arising from swamps. Even yet many people believe this, though there is no longer any excuse for their doing so except ignorance of ascertained facts. Yellow fever was long looked upon as a perfect example of contagion from filth and effluvia; in no other case was the demonstration apparently so clear; and the most elaborate precautions were taken in subjecting to renovating processes baggage and cargoes from infected ports. It is even said that an assiduous quarantine officer once deemed it necessary to disinfect a barrel of carbolic acid. But now we know that yellow fever is conveyed by the bite of a particular kind of mosquito after feeding on the blood of a yellow-fever patient, and in no other way. Baggage, old clothes, or filth of any sort have nothing to do with it, except in so far as they may be resting places for mosquitoes, and the most rigid cleanliness is of no avail if the infected mosquito is allowed to be abroad. Malaria was the basis of our belief in the miasmatic origin of disease, and here, too, the proof seemed to be conclusive; but we now know that the malarial miasma is nothing more intangible than another kind of mosquito, after it has sucked the blood of a person who has malaria. The disease is conveyed by the bite of the mosquito and is not in nature conveyed in any other way. All this has been so clearly demonstrated by numerous experiments that it admits of no further doubt; and if we could destroy all the mosquitoes of the varieties concerned, there could be no more cases of either of these diseases. In the same way it has been shown that plague is transmitted by fleas, typhus fever by body lice, Rocky Mountain spotted fever by a certain species of tick, and a few other diseases by still other insects.

But most of the infectious diseases have modes of transmission that are more direct, and if insects play a part it is incidental and not essential. In such diseases as typhoid, cholera, and dysentery the causative organisms are discharged from the body with the feces and the urine, and the diseases are contracted by the ingestion of food or drink which has become contaminated with these discharges, or by getting into the mouth anything which has been soiled by them. The common fly may be concerned in this contamination, but only by carrying infectious filth mechanically and depositing it on our food. In another group the secretions from the mouth, nose, and throat contain the organisms, and the diseases are transmitted by these bacteria-laden discharges when they are conveyed to the mouths or respiratory passages of other individuals. These are the sputum-borne diseases—a large and important group which includes most of the diseases commonly known as contagious. In yet another group—the venereal diseases—the infecting agents are found in the genital secretions or in discharges from genital lesions, and the diseases are conveyed to other people as a rule by these discharges. In a few communicable diseases the causative organisms are given off in the discharges from open sores, and the diseases are transmitted by such discharges finding their way into scratches, cuts or abrasions on the bodies of other persons.

Even after it became known that the so-called contagious diseases are caused by living bacteria, it was still supposed that external objects play a large part in their transmission: that houses become infected; that books, old clothes, beds, carpets, and furniture harbor the organisms indefinitely and transmit disease through the air after days or weeks or months; that filth and refuse, and the soil, are favorable culture grounds for disease germs and are potent agencies in keeping infections going. Thanks largely to the work of Chapin[1] in collecting and interpreting the evidence, we now know that these things are of very minor significance. There is no longer any reason to believe that the vast majority of disease-producing bacteria develop apart from their human host under ordinary conditions, or that any of them, even under the most favorable circumstances, have more than a very limited growth outside the body. In the main they are obligate parasites; that is, they grow and reproduce themselves only in the favorable soil of the secretions or tissues of the body of their host. Furthermore, it has been proved that the bacteria of most of the infectious diseases die off quickly under the influence of drying and light, and have but a short life when discharged from their natural soil in the body. Objects that are infected with disease-producing bacteria are capable, therefore, of transmitting disease for only a short time; and then only by such intimate contact as will bring about the transference of their contained or adherent organisms into the bodies of new individuals, by the hands or in other ways. For bacteria are solid bodies, with weight and substance; they can not fly about of their own accord or travel through the air unaided; they go only where they are mechanically carried.

IMPORTANCE OF CONTACT.

With the exception of the diseases that are conveyed by insects and the few that are commonly borne by contaminated water or milk, the accumulating evidence is making it more and more evident that the majority of transmissible infections are passed with relative directness from one person to another. Just as we were long ago compelled by increasing knowledge to give up leaky plumbing, sewer gas and rotten potatoes as original causes of communicable diseases, so are we now compelled to give up analogous things as agents of their transmission. The facts all point toward the relative unimportance of the environment, and toward the relative importance of the infected human agent. We are coming to understand that people themselves are the chief agents of disease transmission as well as the only sources of infection, and that the thing of most importance is the actual presence of the infected person. The most frequent way in which his infection is passed on to another is through the relatively short and direct channel of contact. It should be emphasized here that simple proximity is of relatively small importance. Approach may be very near and still be entirely free from danger if no contact is established.

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[1] Chapin, Sources and Modes of Infection, N. Y., 1912.

But contact in this sense, and as now commonly used in discussions of public hygiene, means more than actual touch between persons. It means rather contact with infected secretions while they are still fresh and virulent, whether still on the person who produces them or on things that he has soiled, its essential feature being that it is nearly related in time and space to the escape of the infecting agents from the infected body. But contact alone, as of the hands, with disease-producing bacteria is not sufficient to bring about disease-producing infection; the organisms must find their way into the bodies of their new victims. As a rule they can not enter through the intact skin. They must be implanted on a moist mucous membrane, directly by the fingers, or with food and drink, or in some other way, before they can produce a disease.

Contact infection of the form referred to may be brought about in many ways. Its classical example is found in the mouth to mouth contact of kissing, but others which are less direct are in the aggregate vastly more important. When we cough, or sneeze, or speak very loud, we expel a finely divided and invisible spray of the secretions of the mouth or respiratory passages into the air about the face. Unless borne up by currents of air this spray is not carried more than a few feet, and it rapidly settles upon the floor or surrounding objects where bacteria soon die; but if someone stands near enough to breathe immediately into his lungs our spray-laden expelled air, he may breathe in also the droplets that we have expelled and may get such infections as we have. It should be emphasized, however, that this danger disappears in quiet breathing, for the quietly expired breath contains neither droplets nor bacteria. When we drink from a cup we leave a little saliva on the rim; another drinking may swallow our bacteria, which, if they have not dried, will certainly still be virulent and readily detached. Fingers soiled with urine or feces containing typhoid bacilli may be carried to the lips, or in handling food for another's consumption may contaminate the food and transmit typhoid fever. Sputum deposited on the floor may get onto the hands and be carried to the mouth, or it may be carried away on the shoe soles and deposited elsewhere for the soiling of other hands. The practice of sneezing into the hands or blowing the nose through the fingers always contaminates the hands with nasal secretions, and shaking hands with another person may transfer to him an unseen but still an infectious portion of such secretions. A child may mouth a toy which has touched an infected hand, or which has been picked up from a floor where infected sputum lies.

These are only a few of the ways by which contact may be established. The hands are the most frequent offenders. Few people realize the multiple activities of their hands, or the number of times they touch foreign objects and their own lips and noses. A recent record by Palmer[2] showed in a single ordinary day 92 opportunities for infecting his own hands directly by contact with other hands or with articles just handled by others, 14 opportunities for infecting himself from his own hands by carrying them to the nose or mouth, and 17 opportunities by carrying to his mouth articles possibly infected by others. This is probably not more than is usual for normally active people. According to Rosenau,[3] probably 90 per cent of all infections are taken into the body by the mouth from the hands with food and drink, by the droplets expelled in coughing, or directly by kissing and fondling.

The essential factor in the prevention of communicable diseases is, then, the supervision of individuals having disease germs. Their bodily wastes and discharges must be so disposed of that they will not contaminate the air or the food or the drink that is to be taken into the bodies of other individuals; but chiefly they must be so restrained that they can not transmit their bacteria to healthy people by direct or indirect contact. The proof of the importance of contact has brought about great changes in methods for the control of communicable diseases. It has directed attention to the individual and his habits and away from the condition of his surroundings. While this has made the matter simpler, by narrowing the target at which efforts must be aimed, it has scarcely made the problem easier of solution; for to control the habits of the individual to the end that he may not contaminate with his secretions the things that are about him is a very difficult matter.

CARRIERS AND MISSED CASES.

Along with the demonstration of the part played by contact with ill persons in the transmission of the communicable diseases, we have also learned that there are many infected persons who are not sick, and others who are only so slightly ill that their infections are not suspected. These "carriers" and "missed cases" complicate the problems of prevention enormously. They are potential sources of new cases of actual disease, just as are the cases already sick and identified; and they play a large part in keeping infections going, because they usually fail to come under sanitary supervision.

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[2] Palmer, Opportunities for Contact Infection, Amer. Jour. Public Health, April, 1919, ix, 267.

[3] Rosenau, Preventive Medicine and Hygiene, N. Y., 1916, p. 366.

According to their relation to cases of actual illness, there are carriers of two kinds, which have been classified[4] as active and passive. An active carrier is one who has passed through and recovered from a disease but who has failed to shed all of his infecting organisms. Most cases of infectious diseases remain active carriers for a short time after clinical recovery, some of them remain so for long periods, and a few become permanent, or chronic carriers, continuing to be a menace and a source of infection to well persons. Missed cases act in this regard like those who are acutely sick. A passive carrier is one who harbors in his body the virulent organisms of a disease from which he has never suffered any illness—who has become infected, and in whose body the infecting organisms grow, but whose resistance or natural immunity is so high that the infection does not cause the development of a disease. Under like circumstances we are all about equally liable to infection; that is, to the getting of disease germs into our bodies; but individual resistance and susceptibility vary in a high degree, so that from a given infection one person may develop a disease while another may only become a passive carrier of disease germs, and another still may throw off the germs entirely. Passive carriers are not infrequently found among those who are in close association with an acute case of a communicable disease.

Like the active carriers, they may soon become rid of their germs and return to the normal state; but some of them continue to harbor and expel dangerous organisms through long periods; and it sometimes happens that they themselves later fall victims to the very organisms which they have long harbored without harm and develop the diseases which these organisms cause.

As knowledge of carriers has developed it has become apparent that there are many of them, but the number varies greatly in different diseases. It has long been known that a large proportion of the people, from 20 to 50 per cent of them, have pneumococci in their mouths. While many of these pneumococci have little or no virulence, many are known to be highly virulent and quite capable of producing disease in an experimental way. "During outbreaks of cerebrospinal meningitis the number of carriers may be from 10 to 30 times as numerous as the number of cases. Even when diphtheria is not prevalent 1 per cent of the population may be carrying the bacilli, and during outbreaks the number may be several times greater. Probably 25 per cent of all typhoid fever cases excrete bacilli for some weeks after convalesence, and it is estimated that from 1 in 500 to 1 in 250 of the population are chronic carriers. What little evidence there is indicates that carriers are as numerous in cholera and dysentery [in those regions where these diseases are endemic] as they are in typhoid fever."[5] In malaria, carriers are known to be very numerous, and a considerable proportion of the cases of venereal diseases become chronic and remain infectious for a long time. At the other extreme are measles and smallpox, where the evidence seems to show that the carrier state is rare.

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[4] Simon, Human Infection Carriers, Philadelphia, 1919.

While we have not enough evidence to show clearly just what is the relative importance of carriers and of sick cases in the spread of the communicable diseases, there is ample epidemiologic evidence that healthy carriers may be the source of well marked outbreaks of some of the most common of them. And, as Chapin says, "any scheme of ultimate control which fails to take into consideration carriers and missed cases is doomed to at least partial failure." A practical plan to discover and cure carriers is indeed one of the most urgent needs of sanitary science at this time. The railroads can neither discover them nor prevent their traveling.

TRANSPORTATION OF PERSONS HAVING COMMUNICABLE DISEASES.

The control of communicable diseases on the railways does not differ in its essential features from their control in other places. It nvolves (1) supervision of the person who is known to be infected, ither by preventing his traveling, or by such measures as will render is presence on a train harmless to others; (2) such measures of leanliness and general hygiene as will render unlikely the indirect ransfer of unknown infection among travelers to healthy persons hrough the medium of such things as towels, drinking cups, and ther objects of personal or common use; (3) the control of food nd water supplied on trains and at stations, to the end of assuring heir freedom from contamination with disease-producing bacteria rom the secretions of infected people.

TRAVEL OF UNKNOWN CASES.

Obviously, when food and water have been made safe, the simplest nd most direct plan of further protecting those who travel is to eep out of cars all persons who are infected with the organisms of ommunicable diseases. The difficulty in applying such a plan is n knowing who is infected. Patients in the early stages of measles, hooping cough, scarlet fever, etc., before evident symptoms have eveloped and before the patients are actually ill, may enter trains nd reach their journey's end without anyone—fellow travelers, ailroad employees, or sometimes even the patients themselves—beg aware of their condition. People who have recently been exposed o some acute infection may have strong grounds for believing that

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[5] Chapin, Sources and Modes of Infection, 1912, p. 132.

they are coming down with the disease, yet may undertake railroad
journeys without regard to the possible danger to fellow passengers
Or patients in whom a definite diagnosis of a communicable disease
has been made may successfully conceal their symptoms and travel
without recognition, sometimes even with the consent of thei
physicians, thus duplicating a situation that often exists in citie
when people are selfish and short-sighted enough to conceal case
developing in their homes for fear of the inconvenience incurre
through quarantine. Just as the control of communicable disease
in cities is largely dependent on the conscientious reporting of cases
so, too, on the railroads their control depends largely on the conscienc
of the patients who wish to travel.

How many of these various cases are carried, and what harm
each case has done, is of course unknown. While their number i
the aggregate may be large, they can not be more than a very smal
proportion of the total of railway travelers. And whatever hazar
of communicable diseases they hold for well persons with whom
they come in contact is by no means peculiar to railroad trave
but exists to the same extent in all public places where people assem
ble. The railroads themselves are powerless to prevent such patient
from traveling. They are bound by law to furnish transportatio
to those who ask for it, and they have little power to discriminat
among those who may apply. It is not possible for them to refus
accommodation except under well-defined conditions, which, in so f
as the communicable diseases are concerned, must include a defini
diagnosis; and this the railroads can scarcely be prepared to mak
under the ordinary conditions of travel. Their employees can hav
but slight knowledge of the symptoms of such diseases; and yet t
public health laws and sanitary regulations of some of the Stat
are so framed as to put on the railways and railway employees t
whole responsibility for preventing travel on trains of persons su
fering from communicable diseases. This makes the regulatio
worthless from a practical standpoint, or of value only in cas
where the symptoms are so evident that doubt is impossible; a
under such circumstances there is little likelihood of any attem
being made to travel.

While it is entirely proper that the railroads should not knowing
accept cases of communicable diseases for travel unless prope
safeguarded, and that laws should embody this idea, yet legal regu
tion should also fix the responsibility where it really belongs; t
is, upon the traveler who knows or suspects that he is infect
In the nature of things he is the one most likely to be inform
and regulations should make it unlawful for him to apply for
accept transportation unless his disease is properly announced a
safeguarded. It is scarcely necessary to add that the same conditi

should apply to the parents or guardians of children who are ill, or to anyone in charge of a patient afflicted with a dangerous communicable disease.

Legislation to this purpose has been passed in one form or another in many of the States and has been embodied in the interstate quarantine regulations of the Federal Government, but there has been little concerted effort to enforce its provisions or to make them generally known. The regulatory measures should be extended and made uniform, so that all parts of the country may have similar practices. When a uniform code is adopted it should be extensively printed and distributed, so that both railway patrons and railway employees may learn of the conditions under which travel is permitted and know how to comply with the conditions imposed. It is not to be supposed that compliance will be universal, even if everyone is informed, but regulations in this matter may have a definite and considerable restraining value if their provisions are made known to and impressed upon the public. In all administrative efforts to control communicable diseases success is won slowly and is largely dependent on the general diffusion of knowledge concerning what is the right thing to do.

There will remain the uncontrolled and uncontrollable travel of carriers—uncontrollable because under present conditions they are largely unknowable. The general teaching of habits of personal care regarding the disposal of bodily wastes, especially the secretions of the nose, mouth, and respiratory tract, will do something to lessen their danger in railway cars as elsewhere. The importance of such habits in the practical prevention of respiratory diseases is so well demonstrated that unusual emphasis upon the proper disposal of sputum has become an essential element in all effective public health administration. Railway travel necessarily involves a considerable amount of personal proximity among a miscellaneous group of persons. They should all be informed regarding droplet infection from coughing and sneezing, as well as regarding the various modes of direct and indirect contact infection; and they should all learn that at least some cases of infectious diseases may be prevented by smothering coughs in handkerchiefs, by spitting only in cuspidors, and by maintaining sputum-free hands and surroundings. Such teaching can not by any possibility do harm and it may, if effectively followed, do much good.

TRAVEL OF KNOWN CASES.

The railroads are sometimes called upon to carry patients known to be suffering with communicable diseases, and there often seem to be good reasons why they should do so. Should transportation be refused to all such cases, or can their transportation be so safeguarded that there is no danger to other passengers?

In the present state of our knowledge of the routes of infection and methods of prevention, it is theoretically possible to safeguard a known case of any disease so that its transport will be safe. Practically, however, it is desirable to make exceptions, and to say of certain diseases that they may travel under restrictions while others may not travel at all. There have been differences of opinion among public health authorities, and more among law makers, as to just what diseases should be included in this forbidden group; and the regulatory measures have been various in consequence. Some States have included all communicable diseases, without name or qualification; others have included by name most of the common infections; while others have shorter lists, with sometimes strange combinations. Indeed, there is little harmony or agreement in the laws of the various States on any of the phases of communicable disease control, as evidenced by the fact that the number of diseases which they designate as "dangerous to the public health" and bring under any kind of regulation varies from more than 50 to less than 10.

PERSONS FORBIDDEN TO TRAVEL.

While the tendency of the State laws has been toward a very broad prohibition of travel by persons with infectious diseases, there has been great dissimilarity in the methods devised to make their control effective. In an analysis of the laws and regulations concerning the communicable diseases made by Kerr and Moll [6] in 1913 the legal restrictions of travel were found to be as follows:

> Traveling of persons with communicable diseases is specificially forbidden in some States,[7] and in others [8] unless authorized by the health authorities. In some States the transportation of such persons is prohibited,[9] or it is made punishable to bring them into the State.[10] In others, their being put on board any train or public conveyance,[11] or their going from one town to another is prohibited,[12] one State board of health [13] being specifically authorized to restrain or prohibit travel of persons with communicable diseases on public conveyances. Persons with communicable diseases are forbidden to enter public conveyances in many States either absolutely [14] or unless they make known the fact to the owner or driver, who must disinfect the conveyance immediately after such occupancy.[15] In other States, by regulations of State boards of health, persons from infected premises are forbidden to enter public conveyances,[16] or persons who have visited such premises before entering conveyances must disinfect

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[6] Kerr and Moll, Public Health Bulletin No. 62, Government Printing Office, Washington, 1914.

[7] Indiana, Kansas, Mississippi.

[8] Kentucky.

[9] Indiana, Kansas, New Jersey, South Carolina, Texas, Wisconsin.

[10] Michigan, Oregon.

[11] Iowa.

[12] Vermont, Virginia.

[13] Montana.

[14] Arizona, Connecticut, Florida, Georgia, Idaho, Indiana, Kentucky, Michigan, Minnesota, Montana, New Jersey, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Washington, Wisconsin.

[15] District of Columbia, Louisiana, Maine, Maryland, Pennsylvania.

[16] Illinois, North Dakota.

> their clothes and obtain the permission of the health authorities.[17] * * * Persons coming from infected territory may, by express authority in law, be restrained from traveling by local health authorities in many States;[18] while in various States it is specifically provided that removal of infected or exposed persons from place to place can only be made with the consent of the local health authorities,[19] or either the State or local health authorities.[20]

Since this analysis was made there have been some changes and additions which invalidate the quoted summary as a guide to legal action; these will be referred to later; but to a large extent the matter stands now as it did then, State laws remaining variable and inharmonious when they should be uniform. Health and diseases do not recognize State limits; neither should the regulations which seek to control them change when these limits are passed. Even health officers have not encyclopedic minds for sanitary law, and we can scarcely expect of travelers and transportation agents that they will learn a new set of sanitary rules each time they cross a State border. It is true that the National Government may, and to some extent actually does, regulate interstate quarantine; but under our system of government the State must remain the chief legislative unit, and only when State enactments become uniform may we hope for the development of such a general knowledge of quarantine regulations as will ultimately lead to general compliance with them as they apply to railroad travel.

It is not a matter to be decided offhand just which diseases should be forbidden on trains and which ones should be permitted under proper restrictions; but there should be some rule adopted which is possible of general application, with an attempt to harmonize under the well-established principles of sanitary science the interests of the railroads, the traveling public, and at the same time to preserve the public health. I believe these conditions are met by excluding from travel persons ill with any of the major quarantinable diseases—plague, cholera, yellow fever, typhus fever, and smallpox—and allowing those ill with other diseases to travel under proper supervision. The five diseases named should be excluded from travel because, first, they are (with the exception of smallpox) not commonly present in this country, but when once started in a community have enormous possibilities of epidemic spread; second, their presence is excessively disturbing to the public peace of mind; third, they are known throughout the world as the major quarantinable diseases and are subjected to detention wherever they may be found.

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[17] Kentucky, South Dakota.

[18] Alabama, Colorado, Florida, Maine, Massachusetts, Michigan, New Mexico, North Carolina, Washington, etc.

[19] Colorado, District of Columbia, Louisiana.

[20] Arizona, North Dakota, South Dakota.

Most of the communicable diseases which are commonly known at large we have everywhere, and to some extent all the time. It is so with diphtheria, measles, scarlet fever, typhoid fever, pulmonary tuberculosis, and others. They are endemic. A case more or less is important enough, but it brings no new factor into the public health problem as a rule. Health officers and the public are accustomed to dealing with them and do not become excited over them. It is not so with plague, cholera, yellow fever, and typhus fever To introduce a case of one of these into any community in the United States is to introduce an entirely new public health problem and to interfere in many ways with commercial and social activities. They are, furthermore, acute and violent infections which soon come to an end, either by recovery or death; and at whatever expense of time or trouble to the community, or of discomfort and unhappiness to the patient and his friends, they are best cared for by isolation in the community where they are first discovered and as near the point of origin as is reasonably possible.

It is not because the four diseases referred to can not be transported safely that they should be forbidden to travel, but because they are so disturbing during the journey and on arrival in a new community. We know in great detail how the causative organism for each of them passes from person to person and the means which are necessary to prevent their spread. Plague (except the pneumonic type) is transmitted by the bite of an infected rat-flea, yellow fever by the stegomyia mosquito, and typhus fever by the body louse. No fleas, no bubonic plague; no mosquitoes, no yellow fever; no lice, no typhus fever. If we can be perfectly sure that the patient and his quarters are entirely free from the insects concerned, and that none will by any chance gain access to him, the protection of other people is assured. Being perfectly sure of this is of course a task involving difficulties and the most painstaking care, with always the possibility of something going wrong; but with sufficient care the danger may be entirely overcome. Cholera is transmitted by the vomit and alvine discharges, through contact, or water, or food; and the obvious means of preventing its spread is the prompt and perfect disinfection of vomitus and feces. With this assured the cholera patient might travel without doing harm. But as with plague, yellow fever, and typhus fever, the disease is normally foreign to our shores; our only experience of it is that of disastrous epidemics; and if it is introduced at all it should be strictly held in place until all danger of transmission to other people is past.

Smallpox, on the other hand, is an endemic disease, and most communities are in some degree prepared to deal with it; but it is acute and serious, is known to be very readily communicated, and there is no disease more capable of disturbing the public mind.

Furthermore, we do not know the causative organism, nor precisely the mode of its transfer. We are therefore relatively ill equipped to prevent transmission of smallpx infection to susceptible individuals. It is beside the mark to say that except for ignorance, neglect, and the misguided opposition of the antivaccinationists we should have no susceptibles to smallpox, since in vaccination we have a safe and nearly perfect prophylactic. With rigid rules for universal vaccination the disease would no doubt practically disappear; but under present conditions there will remain enough susceptibles so that no community can feel safe while smallpox is about, and as long as this is the case the disease should be excluded from railway travel.

A move toward uniform regulations, embodying the program suggested above, was made in May, 1920, when a "Standard Railway Sanitary Code" was approved by the Conference of State and Provincial Health Authorities of North America and recommended by the conference to the several States for adoption as a part of their sanitary regulations—a program which was later approved by the United States Public Health Service in conference with the health officers of the States. That code prohibits entirely[21] the travel on railway trains of plague, cholera, yellow fever, typhus fever, and smallpox, and allows other communicable diseases to travel under very strict supervision. Twenty States[22] have already officially adopted the standard code as a part of the State sanitary regulations, and many State health officers have signified their intention of taking similar action. The essential provisions of the standard code have also been incorporated in the last revision of the Interstate Quarantine Regulations, issued in May, 1921, which apply to all travel from one State into another, so that uniform provisions concerning the travel of communicable diseases now have a very wide application.

RESTRICTED TRAVEL.

As already stated in the preceding section, except as recently altered by the adoption of the Standard Railway Sanitary Code the regulatory measures of the States concerning the travel of communicable diseases have been chiefly of a prohibitive nature. In many States the prohibitions have been written into the statutory law. As new knowledge is acquired it should be possible for some small body of experts to apply it at once by a change in the regulations, without waiting for a legislature to meet or to convince its members, often ill informed on scientific matters, what administrative measures the public health requires. To change a law is always a difficult thing;

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[21] Sections 1 and 2 of the Standard Code. See Appendix.

[22] Alabama, Florida, Georgia, Illinois, Kansas, Kentucky, Louisana, Maine. Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia. West Virginia, Washington. Wisconsin.

for a State board of health to change a regulation is relatively very simple, and all necessary power to make public health regulations should be delegated to them. Great harm is sometimes done, and antiquated rules—generally more honored in the breach than in the observance—are often kept in force because sanitary codes are enacted into law.

It is only since 1916, when the United States Public Health Service first officially recognized the occasional necessity for the travel of communicable diseases and attempted by means of the Interstate Quarantine Regulations to put proper safeguards about it, that any of the States have modified the prohibitive provisions of their sanitary codes. A few States soon followed the interstate lead. In 1917 the Oklahoma Board of Health passed regulations which specify restrictions under which many communicable diseases may be accepted for transportation, following closely but not quite duplicating the interstate regulations made in the previous year. At about the same time the Washington State Board of Health adopted the Interstate Quarantine Regulations in their entirety; and Kansas and Montana followed with rules which were the same so far as this portion of them is concerned. Early in 1920 the North Dakota board also adopted the Interstate Quarantine Regulations. In the case of Washington and North Dakota, however, old rules were left in force which prohibited entirely the travel of some diseases which the interstate regulations provided for, leaving the actual conditions there in more than a little doubt. But at any rate the attempt of the Public Health Service to solve a difficult problem started a movement away from strictly prohibitive measures which the action o the Conference of State Health Authorities in approving a Standard Railway Sanitary Code and recommending it to the variou States for adoption has recently carried far forward.

It is wise to discourage the travel of those who are ill of the communicable diseases, both for the good of the public health and for th good of the patients themselves. For those who are seriously sic any considerable journey may involve no little danger, a fact whic is fortunately so well recognized as largely to deter them from an attempt at travel in the acute stages of their afflictions. But the are sometimes good reasons why travel should be undertaken if th condition of the patient will allow, of which the following are example A child falls ill of scarlet fever, measles, or whooping cough, and h parents are anxious to bring him home where they can care for hi and also to avoid the danger of contagion to the children where h is visiting. A laborer in a mining camp where there is no hospita doctor, or nurse, and where there is great danger of spreading th infection, develops typhoid fever, and the manager of the camp wish to send him to a hospital where he can have skilled care. A patient with pulmonary tuberculosis wishes to go to a distant sanitarium in search of a cure; or being fatally ill and realizing that his journey in quest of health has been in vain, wants to end his days at home. A person is discovered to have leprosy, and the health authorities wish to send him to a seaport for deportation, if he is an alien, or, if a citizen, to a distant hospital for proper isolation and care.

If provision is not made for such cases as these they will travel anyway, without regard to prohibitive laws, and generally without the safeguards that should always be required. And they ought to be allowed to travel under conditions that will make their travel safe for themselves and for other passengers. Practically the number of such patients, except those with tuberculosis, will always be very small, but their proper disposal is important. There is no doubt that adequate safeguards can be applied, though under present conditions very few transportation agents and practically no passengers understand what they are.

The measures necessary to make safe the transportation of persons with communicable diseases will vary according to the particular disease concerned, being determined by the way in which the infecting agent is transmitted from one person to another, by the virulence of the disease, and by the readiness with which transmission can take place. They may include any or all of the following:

(1) Isolation of the patient in a compartment separate from other passengers.

(2) The care of a responsible personal attendant.

(3) The disinfection of bodily discharges.

(4) The disinfection of eating and drinking utensils.

(5) Provision by the patient or his attendant of special facilities for carrying out these measures of disinfection and for preventing gross contamination of the car and its contents.

It is usual to classify the communicable diseases according to the ways in which their causative organisms are transmitted from one person to another. We may, however, for the practical purposes of an inquiry into the safeguards of transportation, depart from any strictly logical or all-inclusive classification and divide them for convenience into the following groups:

1. Acute sputum-borne diseases.
2. Acute feces and urine borne diseases.
3. Pulmonary tuberculosis.
4. Leprosy.
5. Venereal diseases.
6. Miscellaneous.

1. ACUTE SPUTUM-BORNE DISEASES.

For the purpose of regulating railway travel the acute sputum-borne diseases should be considered to include diphtheria, measles, scarlet fever, epidemic meningitis, epidemic encephalitis, anterior poliomyelitis, pneumonia, influenza, septic sore throat, rubella, chicken pox, whooping cough, and mumps. In a few of these diseases there are other possible ways of transmission than by the secretions of the mouth and respiratory tract—by the products of skin lesions in chicken pox, for instance, or by discharges from the ear in the complications of scarlet fever—and in a few there may be a reasonable doubt as to the method of transmission, as in epidemic encephalitis; but in most of them the sputum stands clearly convicted of carrying the infecting agent, and in all of them it seems reasonably clear that this is the chief of the means by which they are transmitted from one person to another. He who would understand these diseases correctly must keep this well in mind: That the matter of contracting them is a matter of "swapping spit."

The measures to be taken to prevent the spread of contagion from cases of these diseases must therefore be aimed at preventing the transfer of sputum, whether directly in droplets emitted by the patient in talking, coughing, or sneezing, or indirectly by means of fingers, dishes, eating utensils, and other objects which may be soiled with the sputum or nasal discharges. In order that the necessary details may be effectively carried out, isolation and a personal attendant should always be required.

The Interstate Quarantine Regulations and the Standard Railway Sanitary Code provide for the travel, under restrictions, of all of the diseases included in this group as given above. The appropriate section of the Standard Code, which applies by official adoption in Alabama, Florida, Georgia, Illinois, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia, West Virginia, Washington, and Wisconsin, reads as follows:

SEC. 3. *Restricted travel.*—Common carriers shall not accept for transportation on any railway train, car, or other conveyance any person known by them to be afflicted with diphtheria, measles, scarlet fever, epidemic cerebrospinal meningitis, anterior poliomyelitis, mumps, whooping cough, influenza, pneumonia, epidemic encephalitis, septic sore throat, rubella, or chicken pox, or any person known to be a carrier of these diseases, unless such person is placed in a compartment separate from other passengers, is accompanied by a properly qualified nurse or other attendant, and unless such nurse or attendant shall agree to comply and does so comply with the following regulations:

(*a*) Communication with the compartment within which the patient is traveling shall be restricted to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All sputum and nasal discharges from the patient shall be received in gauze or paper, which shall be deposited in a paper bag or in a closed vessel, and shall be destroyed by burning.

(*d*) Said nurse or attendant shall, after performing any service to the patient, at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

The requirements of the Interstate Quarantine Regulations, are the practical equivalent of those above quoted; and they apply to the same diseases, with the addition of Rocky Mountain spotted fever and anthrax. They have the added provisions, however, that the patient shall obtain permits from the State or local health authorities at the places of beginning and ending of his journey, and that the attendant shall obligate himself in writing to carry out the requirements. Regulations in effect in Oklahoma and Montana are practically identical with the Interstate Quarantine Regulations, but they omit from the list of diseases influenza, epidemic encephalitis, and mumps, for which no provision is made, and place scarlet fever with those that may not travel at all, thus agreeing with an older form of the Interstate Quarantine Regulations. All the regulations require the disinfection of the space occupied by the patient immediately after it has been vacated.[23]

There is probably good reason for requiring permits from the health authorities at the points of origin and destination. In any event, the health authorities should be notified of the location of every case of communicable disease within their jurisdiction in order that they may make sure that the public is protected and exercise control over the patient; and no physician should allow his patient to travel without proper notification. The question of terminal disinfection will be considered later. The other measures of the above regulations must be taken up in detail, even though it may involve the repetition of much that is obvious.

1. *Isolation.*—The patient should be placed in a separate compartment entirely closed off from other passengers, and with which only such communication is permitted as is absolutely necessary for his care. This compartment should have separate washing and toilet facilities. The drawing room of a sleeping car fulfills these requirements in detail, having a toilet and wash room directly connected with it. A compartment in a sleeping car or parlor car will also answer well, but is less desirable because of less adequate toilet facilities.

The question arises, however, as to what shall be done when there is no drawing-room or compartment in the train. Theoretically it might be made safe to carry the patient in the body of a sleeping car, in a berth with the curtains hung, where the proper disposal of a few clean sheets will make an effective cubicle; but practically this method can not be carried out with entire safety or without undue annoyance and alarm to other passengers. In some cases where the need for transporting a patient has been very great and other facilities were not available, a baggage car in which a cot has been curtained or screened off has been used. It may be made to answer for short distances only. An empty coach could be used in the same way, but the cost under ordinary tariffs would be equivalent to supplying a private car, and would usually be prohibitive. In general, and for all journeys of considerable length, the private rooms of sleeping cars and parlor cars are the only practical means of maintaining during travel the strict isolation which is demanded. They are generally to be had where the necessity for a long journey exists; and when they are not available it should be considered inadvisable to transport a case of any of the acute sputum-borne diseases.

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[23] Standard Code, sec. 10; Interstate Quarantine Regulations, sec. 10. See Appendix.

Attention must be given to getting the patient into the place assigned to him. If very ill, so that he has to be carried on a stretcher, the only way to get him into a sleeping-car drawing-room or compartment is by passing the stretcher through the window. This is not a matter of much difficulty; but the windows are high and will require either an elevated platform or something to take the place of it, such as a large, flat baggage truck. It must be remembered also that the room has windows on only one side of the car and may be approached from that side only. When the patient is able to sit up and to walk the few steps from the vestibule to his room, he may be brought to the car steps in a wheel chair and assisted in from there by the regular route of entry, or he may be carried in the arms of an attendant. It should be ascertained, before attempting to board, in which end of the car the room is located, and the car should be entered from that end so that traversing the car length may be avoided, with its possible dangers of contact or mouth spray infection. If brought in while other passengers are entering, such contact should be avoided; and it would be well for the patient, while boarding or being put aboard the car, to wear one of the many forms of gauze masks or to wear a handkerchief over his face. In any case, if a sick patient boards a car in the presence of other passengers, and they suspect a contagious disease, alarm may be caused unnecessarily. It is therefore advisable to place the patient aboard either before or after other passengers are admitted when this is possible.

2. *Attendant.*—It is entirely possible to carry out in the private room of a railway car the precautions outlined in the regulations

already quoted. It is of course somewhat difficult and inconvenient, necessitates providing in advance certain utensils and materials, and requires above all the service of a personal attendant to go with and care for the patient. The person who performs this service should have had experience in similar procedures under less trying conditions. An experienced and conscientious trained nurse, or an intelligent and conscientious person working under the direction and supervision of a nurse or a physician, is practically necessary if the measures are to be effective. While attending to or in close contact with the patient it is excellent practice for a nurse to wear a gauze mask, both for her own immediate protection against infection and to guard against the danger of becoming a passive carrier of disease germs.

3. *Care of sputum and nasal discharges.*—The sputum and nasal discharges from patients with sputum-borne diseases contain the causative organisms in large numbers, and their proper disposal is the essential feature of rendering safe the transport of such patients. If they are not properly disposed of—if a patient is allowed to cough and sneeze with an unprotected face, to expectorate carelessly, to contaminate his surroundings with his discharges—there will arise all the opportunities for infection through droplets of mouth spray and through the various methods of direct and indirect contact which constitute the great danger from these diseases. Carelessness not only results in gross contamination of the compartment and its contents but endangers the attendant of acquiring the disease or becoming a passive carrier. Painstaking and exact care in the disposal of sputum is the key to successful control.

All sputum and nasal discharges and discharges from the eye or ear in scarlet fever should be received on gauze or soft paper. These soiled articles should touch nothing but the patient and the nurse's hands, and should be immediately dropped into a vessel containing a disinfectant solution or put into a closed vessel or a strong tight paper bag for future destruction by burning. It is of course impossible to burn waste gauze or paper in the compartment; and if some form of disinfection is not used in place of burning, the attendant must be prepared to remove them when leaving the car and burn them later. Coughs should be smothered in pieces of gauze, to be similarly disposed of. The continuous wearing of a light gauze mask has been proposed. It is, however, a very trying thing for a sick patient to wear a mask all the time, and such a plan will be found impracticable; furthermore a light mask is not a perfect safeguard against the spraying of droplets in hard coughing.

Where the patient is very ill, and is therefore unable to cooperate with the attendant in his care, or where there is copious secretion from the nose, mouth, or ear, travel is inadvisable even under the best conditions and will rarely be attempted. Under such circumstances it is difficult to prevent direct contamination of the pillow or other parts of the bedding unless a rubber sheet is placed under the patient and over the pillow, or a thick pad of absorbent cotton or gauze may answer the purpose as well. If there is need for such protection it should be provided by the attendant and removed with the patient.

Sheets and pillowcases of sleeping cars are of course laundered and sterilized by boiling after each time they are used, so that if they become contaminated it is not of serious moment; but as a part of the general care every effort should be made to prevent their being soiled with secretions, and if any gross soiling takes place they should be immediately removed, placed in a laundry bag or tied into a bundle, and fresh ones substituted. Blankets, mattresses, and pillows are all completely incased in clean linen each time they are used; and if protected with reasonable care should not become dangerous as carriers of infection. The question of their care, with that of the room, after the patient vacates the compartment, will be considered later.

4. *Disinfection of eating and drinking utensils.*—Any dish, table utensil, or drinking vessel that has been used by a patient with a sputum-borne disease should be thoroughly disinfected before it is used by another person, because it is very likely to be contaminated by the secretions of the mouth. There is ample evidence that such contamination is common, and that insanitary methods of washing dishes may have an important influence on the spread of epidemics.

Boiling is usually the surest and best way of disinfecting dishes, but it is impractical under the circumstances of traveling. The best method here is immersion in a strong disinfectant solution for an hour after use. For the purpose of carrying out the procedure, the nurse or attendant must be supplied with a vessel of sufficient size and with material for making up the solution.

Dishes and utensils should not be first washed, but should be placed at once in the disinfectant solution. A 5 per cent solution of carbolic acid is effective and reasonably convenient. It is expensive unless the crude carbolic can be obtained. Other solutions of equal disinfecting value which may be used are chlorinated lime, 3 per cent; formalin, 10 per cent; or compound cresol solution, 3 per cent. There are many commercial preparations made from coal-tar cresols which are efficient germicides in 1 to 3 per cent solutions. They are usually inoffensive in odor, have valuable cleansing properties, do not corrode metals, and do not irritate the hands of one using them. Corrosive sublimate, which would be the most convenient disinfectant to use under the circumstances, is not adapted to the purpose, since it combines with albuminous matter to form inert compounds and thereby loses its disinfecting power; it also corrodes metals badly.

Food remnants and gauze or paper used as napkins should be collected with other similar articles and cared for as outlined in the preceding section. It is now possible to provide practically all necessary dishes and drinking utensils of paper. If this is done it will prove a great advantage, for it avoids the necessity of immediate disinfection, since they may be collected and destroyed with other waste materials. Another plan that is useful and results in avoiding a considerable amount of trouble is for the patient to have his own dishes for use during the trip and to which any food brought to the patient is transferred. If service is had from the dining car, arrangements may be made to keep the first set of utensils that is brought for continuous use during the journey. In either such case the disinfection may be dispensed with and replaced by ordinary washing by the attendant, the utensils not being allowed to leave the compartment.

5. *Attendant's hands.*—In caring for the patient and disposing of the secretions, the hands of the attendant will unavoidably become contaminated with the bacteria of the disease. If not thoroughly cleansed at once and made free from infectious material, they will carry bacteria to the things that are handled and to the attendant's mouth. After any attention to the patient the hands should be thoroughly washed in soap and water, then dipped into a disinfectant solution. A 2 per cent carbolic-acid solution, its equivalent of some of the cresol preparations, or a 1 to 1,000 corrosive sublimate solution will answer the purpose. In a sleeping car drawing room or compartment there will be a private bowl for ordinary washing, but an extra basin must be carried for the disinfectant solution. Stress should be laid on the preliminary washing.

Summary and comment.—It is evident that the effective care of cases of the acute sputum-borne diseases during travel on railway trains is somewhat difficult. For that matter their effective care is difficult anywhere and requires essentially the same procedures that have been outlined. The sick room at home or in a hospital must have sick-room facilities and equipment; if we travel with the patient we must take the equipment with him and arrange for the proper use of it. This should be impressed upon those desiring to arrange for the transport of infectious diseases. The steps of the procedures must be made clear beforehand, and the articles which it is necessary to bring to the car with the patient must also be made known. These are, in brief: (1) Pieces of gauze or absorbent paper for collecting discharges and for preventing mouth spray in coughing. (2) A strong paper bag or a closed vessel to receive soiled gauze or paper and other contaminated wastes. (3) A receptacle for disinfecting dishes (unless paper dishes are used). (4) A basin for disinfecting he hands of the attendant. (5) Rubber sheeting for protecting the bedding. (6) Disinfectant for making up solutions fo of dishes and hands and for the disinfection of secretions.

It may be contended that the proposed regulations are so as to become a practical prohibition of travel by those wh with contagious diseases. Certainly they do not make tra They are not intended to do so. They are intended to mak which it must be if it is to be done at all: the precautio sick room at home must be continued in the car. But th travel possible when the need is great; and the procedures are really simple enough when the principle underlying them is comprehended. They are all directed to the end of break links of contact between the sick and the well, which are through the agency of mouth and nasal discharges.

It may also be questioned whether all of the diseases enum in this group should be subjected to the same stringent requir in traveling. Some of them are mild and relatively ha Chicken pox, German measles, and mumps, for instance, rar dangerous diseases, and in some of the States are not even sub to quarantine. There is, however, the constant possibility German measles may be confused with genuine measles, or ch pox with smallpox, which they sometimes closely resemble. K cases of even these mild infections should therefore be forbidd travel on trains in the ordinary way.

The question of influenza is always a difficult one. Its cli manifestations range all the way from the slight indispositio common colds to the most serious and profound intoxications. times of epidemic the disease spreads so rapidly that there can b doubt of its high contagiousness, and many of the States have pla it in the strictly quarantined class. There will no doubt be m cases going about in many places, but it would nevertheless s proper to hold the known case strictly isolated and to forbid him use of space in common with healthy people.

The common colds, the mild sore throats, and the nondisabl common infections of the respiratory tract are also sputum-bor but it would be worse than useless to attempt to prohibit to tho who have them the use of public places or the public means of tran portation. Our only practical safeguards against them lie in ev lastingly repeating the admonition to cleanly personal habits, esp cially against the promiscuous distribution of sputum and mout spray and the careless mouthing of fingers or other things that ma be soiled with infectious discharges.

2. ACUTE FECES AND URINE BORNE DISEASES.

The chief diseases of this type are typhoid and paratyphoid fever, the various kinds of dysentery, and cholera. The last has been

The sections of the Standard Railway Sanitary Code dealing with the local-borne diseases read as follows:

Sec. 4. Typhoid and dysentery.—Common carriers shall not accept for transportation on any railway train, car, or other conveyance any person known by them to be affected with typhoid fever, paratyphoid fever, or dysentery, unless said person is a compartment separate from other passengers, is accompanied by a properly

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¹ Quoted from McNutt, A Manual for Health Officers, N. Y., 1915, p. 194

² Hygienic Laboratory Bulletin No. 78, U. S. Govt. Printing Office, 1908

nurse or other attendant, and unless said nurse or attendant shall agree to comply and does so comply with the following regulations:

(*a*) Communication with the compartment in which the patient is traveling shall be limited to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All urine and feces of the patient shall be received into a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value, placed in a covered vessel, thoroughly mixed, and allowed to stand for at least two hours after the last addition thereto before being emptied.

(*d*) A sheet of rubber or other impervious material shall be carried and shall be spread between the sheet and the mattress of any bed that may be used by the patient while in transit.

(*e*) Said nurse or attendant shall use all necessary precautions to prevent access of flies to the patient or his discharges, and after performing any service to the patient shall at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

(*f*) *Provided,* That if a person with typhoid or dysentery is presented at a railway station in ignorance of these regulations, and his transportation is necessary as a life-saving or safeguarding measure, an emergency may be declared and the patient may be carried a reasonable distance in a baggage car if accompanied by an attendant responsible for his care and removal: *Provided also,* That regulations (*a*), (*b*), (*c*), (*d*), and (*e*) of this section shall be complied with in so far as the circumstances will allow, and that all bedding, clothing, rags, or cloths used by the patient shall be removed with him: *And provided further,* That any parts of the car which have become contaminated by any discharges of the patient shall be disinfected as soon as practicable, but not later than the end of the run, by washing with a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

By official adoption of the Standard Railway Sanitary Code these regulations for the travel of typhoid, paratyphoid, and dysentery now apply in Alabama, Florida, Georgia, Illinois, Kentucky, Kansas, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia, West Virginia, Washington, and Wisconsin, and by reason of the practical identity of the Interstate Quarantine Regulations they apply also to all travel from one State into another. The States of Oklahoma and Montana have practically the same regulations as to typhoid and paratyphoid, but they do not include dysentery.

Remembering that the diseases referred to are intestinal diseases, that they are transmitted by alvine discharges, and that there is frequent necessity for the use of the bedpan or urinal in their care, the reason for adding subsection (*d*) will be apparent; it is a reasonable precaution for protection of the bedding from possible contamination and is common practice in hospitals or private houses. The emergency provision of subsection (*f*) is to meet a condition which has been met in actual practice, in removing typhoid patients from branch line mining camps to hospitals for care, in which case the attempt to apply the letter of the regulations might lead to very great hardship and danger.

Departure and arrival permits, as provided in the Interstate Quarantine Regulations, are probably wise requirements in these diseases as in those that are sputum borne; they are practically a part of good communicable-disease reporting. As a matter of fact, many States forbid the removal of any case of a communicable disease to a new location, even within the same health jurisdiction, unless a permit has been obtained. The demand for a written agreement to comply with the regulations would seem to be an unnecessary refinement, which might tend toward the evasion of details. There must be evidence of compliance in fact. That will give the required protection, which the written agreement will not.

It would seem to be hardly necessary to present arguments for the inclusion of paratyphoid and dysentery along with typhoid fever in any travel regulation applying to the latter. From the standpoint of transmission, the diseases are so similar as to make them a natural group, and the measures of control are essentially the same for each.

In carrying out the measures prescribed for making the transportation of typhoid and its related diseases safe, most of what was said in connection with the sputum-borne diseases applies with equal force. There is the same necessity for isolation; for the care of a skilled attendant; and for the disinfection of bodily wastes, of the nurse's hands, and of eating and drinking utensils. The preceding sections should be consulted for details. Only those phases of the subject will be considered here in which there is some difference to be noted.

1. *Isolation.*—The need for isolation of typhoid-fever cases is not so great as for those that are sputum borne. There is no danger from mere proximity, since the danger of droplet infection is practically nonexistent. For this reason a cot in a baggage car is a tolerable condition for a journey of moderate length. There is really no valid hygienic objection to the patient occupying an ordinary sleeping-car berth if proper care and attention to prevent contact infection are provided. The danger to other passengers under such conditions would be negligible, and if the journey may begin and end during the same night it might be permitted with safety. But under the conditions in the open car it is more than a little difficult to give the necessary care to the alvine discharges; and during the daytime, when other passengers are up and about, the use of the bedpan and urinal would be intolerable. So isolation in a separate compartment is a practical necessity, apart from strictly hygienic demands. Indeed, it should be required for all bedridden patients, whether their diseases are communicable or not, except when their journeys may begin and end within the same night. A discussion of the details of isolation will be found under the section on the sputum-borne diseases.

2. *Care of excreta.*—The care of urine and feces is the essential feature of the control of intestinal infectious diseases, and is the chief point wherein the transportation of typhoid and dysentery differs from that of the sputum-borne group. These discharges should be received into vessels (bedpan or urinal) containing a small amount of disinfectant solution. They should then be emptied into another vessel, more disinfectant added, and the contents thoroughly mixed; or an excess of disinfectant solution may be added to the receiving vessel and disinfection finished therein. A quantity of disinfectant at least equal to the total amount of excreta should be added, and if there are any solid portions they should be disintegrated and entirely covered over with the solution. The vessel should be covered and the contents allowed to stand until disinfected. After two hours it may be safely disposed of in any way that normal feces are disposed of. After emptying, bedpans and urinals should be rinsed with the same solution. If it should happen that excreta are collected shortly before arrival at destination and can not be kept the required two hours after adding the disinfectant solution, the vessel may be left in the compartment toilet room for later-disposal by the car-cleaning crew.

A 5 per cent solution of crude carbolic acid may be used for disinfecting urine and feces in the manner above described. Other solutions of equal disinfecting value which may be used are: Chlorinated lime, 3 per cent; compound cresol, 3 per cent; or formalin, 10 per cent. The last named has the advantage of entirely destroying any foul odor; it possesses, however, a pungent odor of its own, which may be somewhat irritating unless the vessel is closely covered.

If there is coughing with expectoration, the sputum should be cared for as described under the sputum-borne diseases; or it may be disinfected with the secretions from the bowel and bladder.

3. *Attendant's hands.*—It has been thoroughly established that the hands of those who nurse or otherwise handle typhoid-fever patients regularly become contaminated with typhoid bacilli. Scrupulous care is therefore necessary if the attendant is to safeguard himself properly against infection by ingestion of bacilli from soiled fingers. After handling the patient, and especially after handling the alvine discharges, the hands should be thoroughly cleansed with soap and water and then dipped in a disinfectant solution. This should be done at once, before other things may have become contaminated by being handled. The details differ in no way from those described in discussing the sputum-borne diseases and need not be repeated here; but the particular source of infectious material should be always borne in mind.

4. *Care of bedding.*—It is to be presumed that patients suffering from typhoid fever can not be transported for any considerable dis-

tance except in a separate compartment of an ordinary sleeping car, in which case all necessary bedding and linen will be furnished by the carrier. It is unnecessary to impress upon those even moderately well trained in the care of such cases that scrupulous cleanliness of the bed and bedding is always necessary. The frequent necessity for use of the bedpan and urinal makes it practically impossible to keep the sheets entirely free from infectious contamination. The use of a rubber sheet for the protection of the mattress is even more necessary in acute intestinal diseases than in that of other diseases. Some such arrangement is a part of the ordinary care of typhoid patients, wherever they may be; and it is properly one of the requirements in arranging for the transportation of typhoid patients that a rubber sheet must be provided and used in the way indicated, as part of the necessary precautions in making travel safe.

With reasonable care, blankets and pillows are not liable to gross contamination. They are, in regular sleeping-car practice, incased in clean linen, which may be changed as often as is necessary. In making up the berth the curtains should not be hung. Any necessary screening may be improvised from sheets. All used linen should be placed in a bag or tied into a bundle by the attendant and kept to the end of the journey; it is, of course, immediately laundered after being released. It is advisable also that blankets be similarly treated, and this is provided for in the regulations.[26]

Summary.—The measures described for the safe transportation of communicable diseases of the acute intestinal type are only the essentials of their safe care and proper isolation in any other place. The facilities and utensils required are those of the sick room. In arranging for the transportation of cases of this kind it should be made clear to the attendant just what it is necessary to provide. The articles are: (1) Disinfectants for making up solutions for the care of hands, of dishes, and of the patient's bodily wastes. (2) A receptacle for disinfecting dishes, unless paper dishes are used. (3) A basin for disinfecting the hands of the attendant. (4) A receptacle for urine and feces and for disinfecting them. (5) Rubber sheeting for protecting the bedding.

3. PULMONARY TUBERCULOSIS.

From the standpoint of railway travel, the only important form of tuberculosis is that which affects the lungs, not only because this is much the most frequent form of the disease, accounting for some 95 per cent of all the cases after childhood, but also because it is the only form from which there is likelihood of spreading tuberculosis infection. The sputum of patients with phthisis is the chief source of tubercle bacilli, and is practically the only medium through which the disease is spread from one person to another. In considering the danger to the public health that may arise through the transportation of tuberculous persons, our inquiry may therefore be limited to pulmonary tuberculosis and to the sputum as the source of infection.

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[26] Sec. 10 of the Standard Code and of the Interstate Quarantine Regulations. See Appendix.

Extent of tuberculous travel.—We have no way of determining accurately the number of tuberculous persons among railway travelers. No census has ever been taken and no dependable one can be taken. Only the very ill can be identified by casual inspection even by expert observers, and the majority of patients will remain undetected unless they declare themselves. But we know that sufferers from pulmonary tuberculosis are great travelers. The reputed curative qualities of the climate of various regions lures them abroad in hope of regaining their health through climatic influences. One place failing, they go to another, and from that to another still; for there will always be some one to tell of the wonders that lie beyond, and the ill are credulous.

Our arid Southwest, southern California, the mountains of Colorado, and parts of the Carolinas bear the reputation of therapeutic El Dorados, and there has been a vast amount of travel to these regions by the tuberculous in search of health. From an extended inspection of trains in the Southwest, Sweet[27] concludes that the vast majority of cars passing through western Texas and New Mexico carry consumptives at some stage of their journey. He found that the greater number, about 50 per cent, ride in day coaches, while 30 per cent occupy tourist sleepers and 20 per cent are in standard Pullmans. Contrary to what might be expected, he found the local traffic heavier than the transcontinental trains in the number of cases carried, though the latter carried the larger number of invalids. Consumptives, like all other people more or less chronically ill, are as a rule dissatisfied with their surroundings, and many of them even after arrival in a favorable climate wander from place to place in search of better conditions. This, according to Sweet, together with the fact that much of the population of the Southwest is made up of the invalid class, accounts for the heavy local traffic.

In earlier days the resort regions advertised their climatic virtues extensively, until an exaggerated popular belief in their curative qualities was produced; and they welcomed the tuberculous immigrant. Both the advertising and the welcome have now largely disappeared, but without having had any very great restraining influence on the amount of tuberculous travel. Sweet believes that while the transportation of far advanced cases is growing somewhat less, travel in the earlier stages is increasing rather than otherwise. And he finds no reason to doubt the estimate of the National Tuberculosis Association that annually 10,000 consumptives who are hopelessly diseased go into the West to die.

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[27] Sweet. Interstate Migration of Tuberculous Persons, Public Health Reports, Apr. 9, 16, and 23, 1915; Reprint No. 269.

In addition to train inspection, much information concerning the amount of tuberculous travel can be gained from a study of the death rates of communities, estimates of the tuberculous population of certain favored regions, and such hospital and other records as are available. A few years ago the United States Public Health Service made an extensive study of the interstate migration of tuberculous persons on such a basis. One of the investigations was reported by Sweet in the article above referred to, covering the States of Texas and New Mexico. Others were made by Foster,[28] in North and South Carolina; Carrington,[29] in California; and Lanza,[30] in Arizona and Colorado.

The report by Sweet is especially thorough. He found the annual death rate from tuberculosis to be much higher in the resort regions than in other parts of the country. For the 10-year period ending with 1912 it averaged 1,404.6 per 100,000 of population in Albuquerque, 788.7 in El Paso, and 449.2 in San Antonio, against 149.5 in the whole registration area of the United States. In tracing out the origin of the fatal cases, it was found that 91 per cent of those at Albuquerque, 63.4 per cent of those at El Paso, and 52.2 per cent of those at San Antonio were among interstate migrants; and a large proportion of those coming from other States had been in residence so short a time when they died as to leave no doubt that they had come in after the disease was well advanced.

Of the fatal cases in Albuquerque during 10 years, 15.6 per cent died within 30 days after arrival, 46.1 per cent within 6 months, and 57.8 per cent within 1 year. For El Paso the figures were 11.5 per cent within 30 days, 30.5 per cent within 6 months, and 38.8 per cent within a year; but if the cases among the Mexican population of El Paso are eliminated, the figures are practically the same as for Albuquerque, 18 per cent dying within 30 days and 46.7 per cent within 6 months after arrival. In San Antonio 32.7 per cent of the fatal cases had been in residence less than 6 months.

These figures indicate that the railroads are forced to carry many cases of advanced tuberculosis to the resort regions; but they by no means tell the whole story, because they do not include the many hopeless cases which return to their homes. The number actually remaining in the resorts when their condition is hopeless is relatively small. When hope is gone, they go back to their relatives and friends.

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[28] Foster, Public Health Reports, March 12, 1915; Reprint No. 265.

[29] Carrington. ibid., March 19, 1915; Reprint No. 266.

[30] Lanza, ibid., June 18, 1915; Reprint No. 283.

The sanatoria almost invariably return to their homes the far advanced cases, in order to avoid the depressing influences of deaths in their midst, and this is also a general custom among practicing physicians. Furthermore, the various relief societies and State agencies find it cheaper, and also more satisfactory to the patient, to make similar disposition of the indigent cases, since they invariably require much care in the later stages of the disease. All this serves to increase the number of far-advanced cases transported, and incidentally to decrease the local tuberculosis death rate.

From the data obtained in his survey, Sweet concludes that not less than 10 per cent of the residents of the arid regions of the Southwest are tuberculous, or have some member of the family who is so afflicted. In some small towns in western Texas the proportion is said to be as high as 50 per cent, and in most of the towns of New Mexico 20 per cent or more. Most of these cases have come from other localities, for he considers it to be a fact that phthisis develops relatively infrequently among the resident population.

An intensive study in a Texas community of 16,000 recently made by Breed [31] revealed 193 cases of tuberculosis, 172 of which had come from other places because of their disease, and 100 of which had been in residence less than a year. A third of all the cases had been "wandering about" for their health.

Investigations in the Carolinas, California, and Colorado and Arizona gave results similar in kind to those reported for Texas and New Mexico by Sweet, though differing considerably in degree. For all regions the figures, while affording no basis for an accurate determination of the amount of tuberculous travel, indicate that it must be very large to all resort regions. That there must be much of it also in other parts of the country is apparent when we remember the great prevalence of pulmonary tuberculosis, its slow and chronic course, and that a large proportion of its victims go about their ordinary affairs for months or even years after they have become diseased. Of these last, there are many thousands who daily mingle with the public everywhere.

It will be clear from the above that a large number of consumptives are carried on the railways. In what way and to what degree are they a danger to the traveling public? And does the danger cease when the consumptive disembarks, or is it possible that the car he has occupied may become a source of danger to future occupants? Even with all the available facts in hand, no direct and positive answer to these questions is possible, because our knowledge of tuberculosis is not yet complete. But many facts have been brought out in recent years which tend to clear the situation and enable us to approximate the truth. That the danger is less than writers of even a decade ago commonly asserted, I believe is true; that it is something can not be denied. A brief review of our present conceptions of the epidemiology of tuberculosis is necessary for a proper consideration of the questions.

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[31] Breed, A Study of the Indigent Migratory Consumptive Problem, Am. Rev. of Tuberc., 1921, iv, 866.

Modes of tuberculous infection.—In order that we may know the dangers of tuberculous infection and be able to apply the measures necessary to prevent it, the way in which tubercle bacilli enter the body must be definitely known. The question of methods of infection is therefore of paramount interest.

The three obvious portals for the entrance of tubercle bacilli are the respiratory tract, the digestive tract, and the skin or mucous membranes; by inhalation, by ingestion, and by inoculation, respectively. Each of these modes of infection is possible, and has been proved to be so both experimentally and clinically. From the fact that the disease is usually located in the lungs inhalation has been considered by many authors to be the most important of the three, but the indications of modern investigation are that ingestion will be found to be of very much greater importance. Infection by inoculation is rare.

It is conceivable that infection by inhalation may be brought about by inhaling dust from dried and pulverized sputum, or by inhaling droplets of mouth spray in the immediate neighborhood of coughing consumptives. Both ways are believed to be possible, but their relative or absolute importance in bringing about infection under natural conditions is not certain. Sputum, by reason of its content of mucus, is not readily pulverized. The making of dust from moist sputum is a prolonged process even under the most favorable conditions, requiring an interval and an environment which are more than likely to destroy or to render innocuous any bacilli which it contains. Tubercle bacilli, especially if exposed to light—and light is almost necessary for thorough drying—do not well survive the pulverizing process. Direct sunlight kills them quickly, and even diffuse light kills them in a few hours or days. ''It is exceedingly rare,'' says Fishberg,[32] ''to find a house where proper precautions are taken as to expectoration in which the collected dust shows virulent tubercle bacilli. Even in houses inhabited or frequented by consumptives—sanitariums, dispensaries, railroad stations, cars, etc.—no dust containing virulent tubercle bacilli has been found in most cases investigated. * * * Dust collected in the streets hardly ever shows the presence of living tubercle bacilli.''

It is doubtful, furthermore, if dust from dried sputum is often raised to such a height in houses as to reach the ordinary breathing zone of adult inhabitants. During vigorous sweeping it may be, but otherwise it is not likely. Under natural conditions the dosage of tubercle bacilli which might be acquired from such a source would ordinarily be small, and it has been shown that small numbers of bacilli can be readily disposed of by the human organism. The experimental evidence on which the dust-infection theory rests has, on the contrary, usually dealt with very heavy artificial dosage; or when it has been otherwise the results have been mostly negative. When all the facts are considered, the dust-infection theory, in its attempt to account for most, or even many, tuberculous infections under natural conditions, rests on an insecure foundation. It must be kept in mind, however, that certain kinds of dust, particularly the sharp particles derived from stone and metal, injure the lungs in such manner as to predispose to the development of pulmonary infections. Excessive dustiness is therefore to be avoided, regardless of whether the dust may be contaminated with tuberculous sputum.

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[32] Fishberg, Pulmonary Tuberculosis, 1919, p. 42.

Careful research has proved that the air exhaled by consumptives during quiet breathing is free from tubercle bacilli, but the fine moist droplets of saliva and mucus emitted from the mouth while talking, coughing, or sneezing do often contain bacilli. Fluegge and his followers believe that the inhalation of these droplets accounts for the majority of tuberculous infections; other observers, and especially those whose work is more recent, do not. Most investigators have found that when a person is at a distance of 3 or 4 feet from the coughing patient droplets do not reach far enough to become a possible infective agent, excepting perhaps when carried by strong air currents. The bacilli thus eliminated soon sink to the floor, and thereafter become innocuous. Another important factor is that the dose of bacilli which may be thus inhaled is very small, probably not often exceeding the limit of tolerance. There are also many natural barriers against bacilli, either moist or dry, being carried into the lungs by inhalation. The nasal passages, mouth, and throat act as efficient filters, detaining inhaled droplets or dust on their moist surfaces. The mucous and lymph covered walls of the trachea and bronchi also retain impinging particles; and the ciliated epithelium of the bronchial tree maintain a constant outward flow of the surface mucus with all particles that have been caught. So bacilli can not enter the lungs with ease. From animal experiments, Bacmeister [33] found that they only rarely do so, and that the inhalation theory of infection in tuberculosis is very poorly supported. It must be borne in mind, however, that very fine particles of one kind and another may and do enter the lungs with the inspired air, as is evident from the common finding of carbon pigment in the lungs of city dwellers, and it is possible that tubercle bacilli may be thus sometimes brought there. But whether they are likely to cause local infection is a disputed question, with the weight of evidence apparently against it at the present time.

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[33] Bacmeister, quoted by Fishberg, l. c., p. 46.

It seems much more probable, from the evidence we now have, that infection of the lungs with tubercle bacilli is usually by way of the blood stream and lymphatics, and that the common portal of entrance into the body is by way of the mouth and alimentary canal. The vast opportunity for hand-to-mouth infection from raw sputum, which is so carelessly and promiscuously spread about by coughing consumptives, will be readily realized. This is looked upon by Krause [34] as probably the most important mode of obtaining tubercle bacilli. The fact that so many children become infected soon after they begin to play about on the floors or in the streets is a significant fact in support of this view. There is also opportunity for ingesting tubercle bacilli with contaminated food and drink, and especially from eating and drinking utensils which have been used by the tuberculous and have been inefficiently cleansed. Cummings [35] considers the last the major mode of infection. He has done much experimental work with dishes and dish washing, the results of which lend some measure of support to his contention.

The evidence that ingestion, as opposed to inhalation, is the chief mode of tuberculous infection under the normal conditions of living becomes each year more convincing and more generally accepted. Even from dust and moist droplets, infection may be brought about by way of the digestive tract; for what lodges in the mouth is soon swallowed with the saliva, and what lodges in the trachea and larger bronchi is swept back into the throat to be swallowed later; or the bacilli may find entrance to the tissues directly from the throat through the tonsilar crypts and mucosa.

But whatever may be the route by which tubercle bacilli enter the body, there is no dispute of the fact that the sputum of tuberculous people is by all odds their most important and frequent source. Effective preventive measures will therefore require the proper disposal of sputum; and this should be done on the assumption that any or all of the methods of infection proposed may suffice under certain conditions. While it now appears that the greatest danger comes from contact with raw sputum, by manual transfer to the mouth, other things should not be neglected. Sputum must not be sprayed as droplets into the faces of people, deposited on the floor where it may become converted into dust or picked up on children's fingers, allowed to contaminate eating utensils and food, nor spread about in any place where it may become a source of infection through the various forms of contact; for so long as it is indiscriminately spread about, the multitudinous opportunities for infection will remain and the multitude of infections will take place.

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[34] Krause, Essays on Tuberculosis, Journal of the Outdoor Life, 1919, XVI, 106.

[35] Cummings, Jour. Am. Med. Assoc., 1920, 74, 1072.

Extent of tuberculous infection.—The excessive prevalence of tuberculous disease is a fact of common knowledge; the vastly greater prevalence of infection with tubercle bacilli, without the development of disease, is not so commonly known. Investigation has shown that from 80 to 90 per cent of adult human beings who come to autopsy have visible evidence of tuberculous infection somewhere in their bodies, whatever the cause from which they died, and even a larger proportion of the living give the specific skin reaction which indicates such infection, though relatively few of either class show any evidence of the disease in active form. Only in the small minority of those who are infected does the presence of tubercle bacilli in the tissues bring about the changes or cause the symptoms that we know as the disease tuberculosis. The great majority go through life infected, but so far as they know or as can be ascertained they remain entirely healthy and well.

During the first two years of life the vast majority of children are free from tuberculous infection. But as they grow older and begin to run about and increase their opportunities for contact, the proportion found to be infected increases rapidly, so that at the age of 6 about 50 per cent, and at puberty about 75 per cent, are found to be infected. From that time on the proportion slowly increases, until by the third decade infection is practically universal.[36] On the basis of such figures, and they are fully substantiated by numerous investigations, it must be concluded that the tubercle bacillus is very widely distributed and that no one can wholly escape it.

Genesis of tuberculous disease.—It is clear that the presence of tubercle bacilli in the body does not necessarily call forth any active tuberculosis. In spite of our nearly universal infection, the most highly tuberculized community, except in certain regions frequented as health resorts, does not show more than 2 or 3 per cent of active cases at any one time, and but little more than 10 per cent will ever become manifestly ill of tuberculous disease. Just why the few succumb while the majority escape we do not fully know. But to all infections we have some degree of resistance which must be overcome before they produce disease, and in the case of tuberculosis most people have acquired, or in some way they possess, enough resistance to protect them.

That infection with tubercle bacilli is the prerequisite of tuberculosis is beyond a shadow of doubt, but something more than infection alone is needed to bring about active tuberculous disease; resistance must be overcome by the invading parasite. Among a possible multitude of conditions that may determine the overcoming of resistance, and infection becoming disease, two things stand out prominently—large dosage of tubercle bacilli and repetition of the infection. It has been clearly shown that a few bacilli may be successfully taken care of; but massive infection, and small doses repeated frequently enough to amount to that, can not. Of first importance, then, in the campaign against tuberculosis, is the protection of healthy subjects against massive or frequent infection.

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[36] Figures from Krause, Essays on Tuberculosis, Journal of the Outdoor Life, 1918, XV, 163.

It is now fully recognized that the younger the individual the more likely is he to develop acute disease from any given tuberculous infection. Very young children have very little resistance, and succumb most readily when they become infected. One exposure, or a small dose of tubercle bacilli, may be very dangerous to a small child, whereas the same exposure or dosage may be harmless to an adult. The adult has, in the vast majority of instances, already been infected, probably not once but many times, and he bears the evidence of it in his body. It is more than probable that in the very process of overcoming these past infections he has developed the immunity that now in a large degree protects him. There is no doubt whatever that some change takes place in the body as the result of infection with tubercle bacilli which renders its reaction to further infection different from the reaction observed in the infection of virgin soil, something which renders the individual more resistant. The young child is virgin soil. As time goes on its tissues will inevitably become the seeding ground for tubercle bacilli. The longer the sowing is delayed the better is the chance of its failing to produce disease at once, and the smaller the early dosage of infection the greater is the probability of the child's developing the immunity that will protect his later life.

Many excellent observers now believe that tuberculosis makes only a single invasion in the pathologic sense. This original tuberculous infection may lead to acute and generalized disease, as it often does in the very young; but in the majority of instances the growth of the bacilli is limited by the development of immunizing substances in the tissues so that they cause only a local lesion, which then lies dormant and protects against reinfection from without. Whether illness will ever develop from the original tuberculous lesion depends on the mass of the original infection and on the various factors of hygiene and intercurrent disease that tend to break down the resistance of the tissues; for all immunity is relative, not absolute.

In such a conception the chronic tuberculosis we see in the period after childhood is only a lighting up and extending of an old and dormant process; it is the growth of an old infection rather than the acquiring of a new one. There is much to support this view. The statistics of hospitals and sanatoria for the tuberculous show that the prevalence of phthisis among the attendants is no greater than in other divisions of the civil population; and these statistics hold good, according to Fishberg,[37] through a period long preceding the modern practice in such institutions of that painstaking care of the sputum which tends to limit the possibility or the massiveness of infection. It has also been observed that the mild case entering such an institution is in no danger of superinfection from the more active cases with which he comes in contact. The course of his disease is in no way affected by such contact. In young children the disease is usually acute, but when adults of primitive peoples among whom tuberculosis has not before existed are first infected from foreign sources, they react as children do and die of acute disease; they have not the acquired immunity which is developed as the result of early and minute doses of tubercle bacilli.

Dangers of tuberculous travel.—The time relation between tuberculous infection and tuberculous disease is so indefinite that in epidemiologic studies we can only generalize, weighing the possible chances of recent infection against those that are more remote. It is rarely possible to know the origin of any case exactly. This makes it difficult to determine the effect on the public health of the travel of phthisical patients. There is little direct evidence in hand, and not a great deal that is obtainable. Interpretation of the danger must therefore be based largely on our general knowledge of the modes of tuberculous infection and the genesis of tuberculous disease. which has been given in outline above.

There are two possible sources of tuberculous infection in railway cars—the patient himself and the car or its furnishings after the patient has left it. From the patient himself the possibility lies in droplets of mouth spray and in the various forms of direct and indirect contact with his sputum; from the car the possibility lies in dried sputum deposits or dust.

It has already been stated, on the authority of Fishberg, that it is rare to find virulent tubercle bacilli in houses frequented by the tuberculous if proper precautions are taken as to expectoration, and that none had been found in public places, such as railway cars and stations, in most investigations. It can scarcely be alleged, however, that railway passengers are a very careful lot. It is not surprising if they sometimes leave behind them sputum containing bacilli, which as a matter of fact they do. Thus Prausnitz[38] and Petri[39] were sometimes able to demonstrate tubercle bacilli on the floors of cars carrying many consumptives to the health resorts of Switzerland and to Berlin during the early activity of the Koch tuberculin treatment, when tuberculous travel was heavy and promiscuous spitting was common.

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[37] Fishberg, Pulmonary Tuberculosis, 1919, p. 122.

[38] Muench. Med. Woch., 1892.

[39] Arb. a. d. kais. Gesundheitsamt, 1894.

Somewhat later, in this country, Kinyoun [40] made an extended investigation of the bacteria to be found in railway cars; and he also found tubercle bacilli, but only very rarely. He collected the dust from the floors, carpets, and upholstery, and from the air of cars, and subjected it to microscopic examination, bacteriological culture, and animal inoculation.

He similarly tested the material gained by rubbing with moist swabs the interiors of cars. In the many samples which were examined microscopically two were found containing an organism resembling the tubercle bacillus, but identification could not be made complete nor the question of virulence solved. Of 196 guinea pigs which were inoculated intraperitoneally with the dust and other materials, only one developed a positive tuberculosis. When the extreme susceptibility of these animals to very small doses of tubercle bacilli is considered, and that many of the cars examined were running to health resorts in the Southwest and carried many consumptives, the surprising fact is not that tubercle bacilli were found by this very delicate test, but that so few were found.

If the results obtained by Kinyoun may be taken as typical, even though dust were a more potent source of tuberculous infection than is now commonly supposed, it would seem that the chances for infection from this source under the normal conditions of travel must be exceedingly small. There is no natural method of infection which approaches in delicacy and certainty the injection of organisms into the peritoneum, and even to that delicate test for the presence of tubercle bacilli the human being would be many times more resistant than is the guinea pig. The inference seems to be warranted either that few tubercle bacilli are deposited in cars or that the most of them soon die. The number deposited depends, of course, on the habits of those who travel, and the continued crusade against spitting has probably determined that fewer are deposited now than were in former times, but the habits of travelers are not yet as good as is desirable. Good car cleaning would, of course, tend to limit the number found at any time; but the fact that cars have many windows and are freely flooded with sunlight, known to be destructive to the life or virulence of tubercle bacilli, is probably of the greatest importance in determining the meager findings that have been made.

The facts as outlined seem to indicate that the danger of acquiring tuberculous infection from the previously infected car must be very small, and the tuberculous fellow traveler becomes the matter of most importance from the standpoint of public health. It is highly probable that tuberculous infection is contracted, under natural conditions, chiefly from contact with the freshly voided sputum of those persons who have phthisis. It must be remembered, however, that tuberculosis is an ubiquitous disease. Simple proximity to it is unavoidable. Whenever we go into public places we are liable to come in contact with those who have it. Such danger as that involves is present everywhere. In this regard the railway car differs but little from the theater, moving-picture hall, department store, street car, school, office, and other similar places; all are liable to have in them active cases of phthisis. And active cases of phthisis are the source of tuberculous infection.

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[40] Kinyoun, The Bacterial Content of the Railway Coach, Med. News, July 29, 1905.

It is generally assumed that the danger of tuberculous infection is proportional to the severity of the patient's illness. In general this may be true, but it is not necessarily so. The advanced case may be, and often is, a safer companion than the early case; for many of those who are only slightly sick produce large numbers of tubercle bacilli, and some of those whose disease is far advanced produce relatively few bacilli. It is probable also that the advanced cases have had more and better training in the protection of their surroundings and of those about them. The car is perhaps more likely to have in it actual invalids than are other public places; but these will at most make up only a small proportion of the total cases met with and need not add materially to the danger, which depends far more on the habits of the patient than on the stage of his disease.

So far as the danger of infecting adults is concerned, the vast majority of them have already been infected with tubercle bacilli and have acquired the relative immunity to further infection from without which is conferred by overcoming an infection in early life. Lowered resistance and breakdown, not an immediately preceding infection, sets the date for the onset of phthisis in such persons. But acquired immunity to infectious diseases is rarely absolute; it is only relative—sufficient for the ordinary conditions of life, and failing in emergencies, of which massive infection should perhaps be considered one. The question arises in the case of tuberculosis, Does association in railway cars afford opportunity for the massive infection that might constitute such an emergency? It appears that it does not; for experience has taught us that both prolonged and intimate contact is necessary for such a result, and in ordinary railway journeys neither condition prevails.

It is conceivable that the conditions surrounding railway travel might contribute to the lowering of personal resistance in such a degree as to determine the lighting up of old tuberculous foci. The riding of railway trains can scarcely be called a stimulating occupation; there is involved in it very often a certain amount of irregularity and hardship. Habits of eating, of exercise, of rest, and of sleep may be thrown out of their normal relations; there may be exposure to dust, or to inadequate ventilation and heat; and if journeys are long there may be considerable fatigue for those unaccustomed to travel. But such influences must be much more prolonged and much more marked than they are under the ordinary conditions of travel if they are to attain to much importance in bringing about such a result.

If railway coaches and sleeping cars were a potent source of tuberculous infection or had any perceptible influence in causing the development of tuberculous disease, we should expect this fact to appear in its influence on the health of those employees who are obliged to spend a large portion of their lives in these cars—we should expect to find a high tuberculosis rate among passenger-train conductors, passenger brakemen, and sleeping-car conductors and porters. Unfortunately there are very few exact data on this point. There is, however, among railway surgeons of large experience, a common belief that the case is otherwise—that passenger-train men suffer rather less from tuberculosis than do other classes of employees. Railways have rarely kept statistics in such detail as will verify the correctness of this view, but we have in figures from the Pennsylvania Railroad relief fund, published by Dudley[41] in 1905, some evidence that supports it. The statistics showed that tuberculosis was more prevalent among freight-train conductors and brakemen belonging to the fund during the 18 years of its life than among the corresponding employees on passenger trains, the average yearly disablement rates from tuberculosis being as follow:

	Per 100,000 per annum.
Disablement rate for passenger conductors	330
Disablement rate for passenger brakemen	120
Disablement rate for freight conductors	400
Disablement rate for freight brakemen	170

The conductors represented in the above groups were mostly older employees who had been taken into the fund without examination, while the brakemen were younger employees who had been examined and pronounced sound before admission. This is supposed to explain the lower disability rate among the brakemen of each class than among the corresponding conductors. It will be noted, however, that both conductors and brakemen on freight trains suffered more disability from tuberculosis than the corresponding groups on passenger trains.

The statistics of deaths from tuberculosis were considered reliable only during the last four years of the period covered by the above figures, during which all cases of illness were carefully followed even after leaving the company's service. The death rates from tuberculosis were as follow:

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[41] Dudley, The Dissemination of Tuberculosis as Affected by Railroad Travel, The Medical News, December 16, 1905.

	Per 100,000 per annum.
Death rate for all members of the fund	90
Death rate for passenger conductors	77
Death rate for passenger brakemen	52
Death rate for freight conductors	100
Death rate for freight brakemen	67

Here again, as in the previous case, the danger of tuberculosis as measured by the death rate in these groups is less for passenger-train men than for freight-train men, and in the case of the passenger-train men both conductors and brakemen show a lower death rate than the average for the whole membership of the fund.

Nor does it appear that railway employees in general suffer more from tuberculosis than do those engaged in other occupations. Indeed, it seems that they suffer rather less than the average. Heminway[42] says, "it appears that those who travel are less likely to consumption than those who stay at home," a statement which he supports in part by the following table compiled from the United States Mortality Statistics for the decade ending 1909, showing the relation of deaths from consumption to the total number of deaths in certain occupation groups:

	Total deaths.	Consumption.	Consumption.		Total deaths.	Consumption.	Consumption.
			Per cent.				*Per cent.*
All occupations	204,975	29,821	14.5	Boatmen	1,706	179	10.5
Steam railroad employees	5,368	386	7.2	Salesmen	2,513	398	15.8
Physicians	1,421	94	6.6	Food manufacturers	3,140	505	16.0
Lawyers	1,325	99	7.5	Street car employees	686	128	18.8
Commercial travelers	540	54	10.0	Bookkeepers	1,702	372	21.8
				Clerks	6,772	1,908	28.2

Regulation of tuberculous travel.—In cars, as everywhere else, young children are most in danger of acquiring tuberculous infection. Not only are they more highly susceptible than older people, and unprotected by the partial immunity derived from overcoming an earlier infection, but they have not acquired those habits of personal cleanliness that come with later years and that are such potent factors in the self-protection against all infectious diseases. Their universal tendency to establish relations with their new world through the sense of taste renders them especially liable to that commonest of all modes of infection—directly from hand to mouth. In every public place they should be kept from playing on floors, where sputum contamination is most likely to be found and where cuspidors may be in all too easy reach of their exploring fingers.

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[42] Heminway, The Transportaion of Consumptives, The Railway Surgical Journal, 1915, XXI, 35.

As we now understand the problem, the limitation of tuberculous disease depends in large measure on the protection of early childhood against infection. While children represent only a small proportion of travelers, from the standpoint of the hygiene of travel they are the most important part and require the most careful protection.

But while the protection of children against infection is more important than that of adults, the interests of the adult, though he is relatively invulnerable, must not be lost sight of or neglected. All measures must be general. Calmette[43] has said, "the guiding principle in the social campaign against tuberculosis is the protection of healthy subjects, whether infant or adult, against massive or frequent infection. This fundamental idea should be made known among the people by every possible means." And because both of the real protection involved and of its educational value, tuberculous travel should be surrounded by restrictions.

In recent years many States have forbidden tuberculous persons to engage in certain occupations, particularly those having to do with the preparation of food and with the care of children, but few have dealt in any way with restriction of their movement, and those few have scarcely gone further than to provide for the moderate restraint of such patients as show themselves more than ordinarily negligent of the simplest rules of hygiene and who persist in their refusal to follow advice. With a single possible exception,[44] none of the States, by either law or regulation has forbidden them to travel, though a few, following the example of the Interstate Quarantine Regulations of 1916, and more recently by adopting the Standard Railway Sanitary Code, have laid down certain conditions with which they must comply when travel is undertaken. The care of the sputum has properly been the point of attack where regulations have been made. The section of the Standard Railway Sanitary Code covering the matter reads as follows:

SEC. 9. *Pulmonary tuberculosis.*—Common carriers shall not accept for transportation any person known by them to be afflicted with pulmonary tuberculosis in a communicable stage unless said person is provided with (*a*) a sputum cup made of impervious material and so constructed as to admit of being tightly closed when not in use, (*b*) a sufficient supply of gauze, paper, or similar articles of the proper size to cover the mouth and nose while coughing or sneezing, (*c*) a heavy paper bag or other tight container for receiving the soiled gauze, paper, or similar articles; and unless such person shall obligate himself to use the articles provided for in the manner intended, and to destroy said articles by burning or to disinfect them by immersing for at least one hour in a 5 per cent solution of carbolic acid or other solution of equivalent disinfecting value; nor shall any person knowing himself to be so afflicted apply for, procure, or accept transportation unless he shall have agreed to and made all necessary arrangements for complying and does so comply with the regulations as set forth in this section.

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[43] Calmette, International Journal of Public Health, July, 1920, I, 3.

[44] New Jersey.

Such are the regulations in the States of Alabama, Florida, Georgia, Illinois, Kansas, Kentucky, Louisana, Maine, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia, West Virginia, Washington, and Wisconsin. The regulations in Oklahoma and Montana, and for all travel from one State into another under the Interstate Quarantine Regulations, are the practical equivalent of the above. It will be noted that under these regulations the responsibility for preventing tuberculous travel lies largely with the individual who has the disease. This provision is a necessary one; for without an obligation being placed on the patient to refrain from traveling or to make his condition known, the railroads have practically no power to make the regulations effective. They can not know the tuberculous individual; the patient should be enjoined to provide the things required of him out of his own initiative and out of his own knowledge of his condition. In the absence of such an obligation, no plan can accomplish much.

Perhaps in the case of phthisis no plan can accomplish very much anyway; but the very greatness of the tuberculosis problem makes every point of attack an important one and every possible means of limiting the chances of massive infection, more especially the infection of children, worthy of such effort as can be accorded to it. The injunction to the tuberculosis patient in traveling is the injunction to the tuberculosis patient everywhere. On the patient rests the responsibility of being careful of his sputum, of avoiding such distribution of it as will render others liable to infection. When he rides in public vehicles his responsibility does not cease, but rather increases, and every means should be taken to bring this fact home to him.

It is scarcely necessary to expand upon the details of carrying out the provisions of the regulations quoted. With the exception of the sputum cup they are simple: Sputum must not be distributed; what is contaminated with sputum must be put away and destroyed.

Concerning the sputum cup, I am not sanguine. I have rarely seen them used outside of institutions. They are too conspicuous to appeal to the average individual as a desirable companion. The destructible paper one is practically hopeless in car service; there is no place to put it when not in use; it soon becomes foul and may readily defeat its own purpose; it is scarcely better than the ordinary cuspidor, which indeed may be used practically without danger to anyone provided it is used carefully and sputum is actually deposited within it. But the metal pocket flask, if properly made, is neither unsightly nor troublesome, is conveniently used and easily put away, and the tuberculous patient who understands and has a sanitary conscience will surely provide himself with one.

4. LEPROSY.

Leprosy is one of the oldest known diseases. It was much more prevalent in ancient times and down through the Middle Ages than it is now, but it still prevails widely in certain parts of the world, such as India, China, Japan, and South Africa. There are many cases in the Philippine and Hawaiian Islands. On this continent the disease is relatively rare, but it exists in the Gulf States, among the orientals on the Pacific coast, and considerably in Mexico.

Leprosy is presumably transmitted by the discharges from the sores which form the open lesions of the disease. These may be located on the surface or in the mucous membranes. The mouth, nose, and throat are favorite locations, but the conjunctiva and the intestinal mucosa may be involved. The sputum and nasal secretions often contain the lepra bacilli in large numbers.

Leprosy was looked upon as contagious in very ancient times. It is now known, however, that the disease is not so easily transmitted as it was thought to be in the past. While we do not know all the conditions necessary, it is evident that the closest and most intimate contact is essential and that the degree of contagiousness is very small indeed. Casual contact is of no significance. The doctors, nurses, and Sisters of Charity who care for leprous patients are very rarely attacked. Rosenau[45] says "there is no more danger from a leprosy patient with clean personal habits, who exercises care concerning the discharges from the lesions, than there is from an open case of tuberculosis of the glands of the neck." The latter is not looked upon with fear, and neither is leprosy in those countries where it is more prevalent and better known; but the fear of leprosy is almost universal in this country, and is a matter to be reckoned with in considering the transportation of leprous patients, for people generally are thrown into a panic by knowledge of the simple proximity of such persons. This attitude probably arises from common knowledge of the cry "unclean" with which leprous persons were obliged in ancient times to warn the public of their presence, and is fostered by sensational newspaper accounts of those cases that become known. Logic plays no part in the reaction, which is founded on ignorance and misconception. But if the fear of contracting leprosy is not well founded, the dread of having it certainly is, because of its mutilating and usually fatal character.

Fortunately we have relatively few lepers in this country, and most of those are under restraint; for in most communities recognized cases are not tolerated at large. There is therefore little chance for lepers to travel on the railways except under the direction of a public health official. Their transportation is nevertheless sometimes necessary. The very fact that the number of cases is small enables us to isolate or deport all cases that are known, and thus to guard against the slow spread of the disease that might take place if the patients were left at large. When a case of leprosy is discovered in a community it should be removed to a Government institution, such as is maintained at Carville, La., for permanent isolation and care, or, if the patient is a foreigner, to a seaport for deportation. In either instance long railway journeys are usually involved in their transfer.

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[45] Rosenau, Preventive Medicine and Hygiene, N. Y., 1916, p. 329.

Leprosy was the first disease for the transportation of which specific regulations were made. The Interstate Quarantine Regulations have contained rules for the safe transport of lepers since 1912. Through various revisions the regulations have come into the following form:

> SEC. 5. *Travel of lepers.*—Common carriers shall not accept for transportation or transport in interstate traffic any person known by them to be afflicted with leprosy, nor shall any person so afflicted accept such transportation except as hereinafter provided.
>
> (*a*) A person afflicted with leprosy shall be permitted to accept transportation upon presentation of permits from the Surgeon General of the United States Public Health Service, or his accredited representative, and from the health authorities of the States, Territories, or District of Columbia to and from which he intends to travel, stating that such person may be received under such restrictions, which shall be specified in each instance, as will prevent the spread of the disease, provided such person shall have agreed in writing to comply, and does so comply, with the restrictions as specified.
>
> (*b*) Any person who presents symptoms of leprosy and who is traveling or who has left the State where he resides in violation of the above regulations shall be detained and, if proved to be a leper, shall be returned to such State or removed to such Federal station as the Secretary of the Treasury may designate, and the proper health authorities notified.

The Standard Railway Sanitary Code has practically the same restrictions. The section pertaining to the transportation of leprosy reads as follows:

> SEC. 8. *Leprosy.*—Common carriers shall not accept for transportation nor transport in any railway train, car, or other conveyance any person known by them to be afflicted with leprosy, unless such person presents permits from the Surgeon General of the United States Public Health Service or his accredited representative, and from the State department of health of the States from which and to which he is traveling, stating that such person may be received under such restrictions as will prevent the spread of the disease, and said restrictions shall be specified in each instance; and no person knowing or suspecting himself to be afflicted with leprosy, nor any person acting for him, shall apply for, procure, or accept transportation from any common carrier unless such permits have been received and are presented, and unless the person so afflicted agrees to comply and does so comply with the restrictions ordered.

By both of these regulations the transportation of cases of leprosy is brought under the direct supervision of the United States Public Health Service and the health authorities of the States of origin and destination, which jointly make rules for each case according to conditions.

The specifications invariably provide that the patients shall be accompanied by a representative of the health department arranging for the transport, that they shall be strictly isolated and under guard, shall have their own eating and drinking utensils, that all discharges shall be disinfected and properly disposed of, and that the space they occupy shall be disinfected after the patients disembark. Such patients are virtually prisoners of the State, and the accompanying officer is responsible for their safe delivery at destination as well as for carrying out all of the sanitary arrangements that may be ordered for the individual case.

Isolation during the transportation of lepers may be carried out in the private room or compartment of any car with perfect safety, though objection is often raised to assigning space for the purpose. The attendant may, as he sometimes does, occupy the room with the patient. When several patients can be taken at once, the better plan, and the one usually followed, is to engage a tourist car or coach to run as a private car for the purpose. In either event, as the matter is actually handled in practice by public health departments, the public is not exposed to any danger.

5. VENEREAL DISEASES.

The common venereal diseases are syphilis, gonorrhea, and chancroid. They are infectious and communicable. Their causative organisms and modes of transfer are well known; they are therefore preventable. By appropriate treatment they are generally curable; but if not treated, syphilis and gonorrhea become chronic and may be indefinitely prolonged.

The venereal diseases are so prevalent as to constitute one of the greatest of modern plagues. No other group of diseases is responsible for so much suffering and continued inefficiency. Their effects extend from the individual to the family, the community, and posterity. They exert a considerable, though unknown, effect on the general death rate.

This would seem to be a combination of qualities well fitted to the health officer's hand: prevalent, and disastrous to the public health; communicable, with the paths of transfer known; preventable and curable. But so vast is the social evil out of which the venereal diseases come, so deeply is this problem rooted in human life, and so closely is it interwoven with kindred social problems yet unsolved, that the difficulties to be overcome are greater than in any other disease. In spite of the large public health problem which these diseases bring about, no serious attempt to control them was made until very recent years. And no progress in their control was made until a few health officers of larger vision determined to ignore the social and moral aspects of the case and treat these diseases as any other communicable and preventable infection, to remove the veil of secrecy by which they were surrounded and to make them subject to report and quarantine.

This change in attitude is practically limited to the last decade. Previous to that time the venereal diseases were looked upon as entirely private affairs, as just punishments for sins committed; they were not reportable to public health authorities or subject to control in any way. With our entrance into the European war, in 1917, the necessity of protecting the military forces against infection brought this whole question into prominence and gave great impetus to the matter of control. On the simple basis of public health protection, ignoring the social and moral questions involved, laws and regulations were enacted making the venereal diseases conditionally reportable and subject to quarantine in practically all of the States. At the same time an extensive educational campaign was inaugurated and has since been carried on.

It has not yet been determined what good has been accomplished by these regulatory measures, the administrative details of which are still in the experimental stage. Reporting is very imperfectly carried out, and the great majority of the victims of venereal disease still hold their afflictions secret and personal. But the effort to educate the people concerning the nature and significance of the venereal diseases, the suppression of persistent offenders against the sanitary laws, and the opening of many dispensaries for the free treatment of patients can not have been quite useless. Many thousands of cases have been treated in the free clinics established by the States, and a large proportion of them have been cured completely or rendered noninfectious, which would have remained infectious under the inadequate care so often provided by personal initiative. Each case so remedied removes one source from which the diseases are spread. Such treatment is one of the most importent elements of venereal disease control.

In drawing up the Standard Railway Sanitary Code the question of including regulations for the travel of venereally infected persons was thoroughly considered, and it was decided to leave them out. That anything useful can be accomplished under present conditions by such regulations seems to be almost hopeless. In spite of all laws to the contrary, the venereal diseases are usually held in secret and will not be declared. The victim is rarely obviously sick, and not often discoverable; and the number of cases is legion. The danger of such persons to fellow travelers is insignificant; for the causative organisms are among the most vulnerable of bacteria, soon losing their virulence outside of the body, and communication of the diseases is rare by any other means than by direct and intimate personal contact.

But indirect transfer by articles freshly soiled with discharges is possible and does occasionally take place. We sometimes see epidemics of gonorrhea among little girls in hospitals for children, from the soiled hands of nurses or from the common use of uncleaned bathing utensils and cloths. Among adults, only the grossest neglect and carelessness will lead to indirect infection. Syphilis is more dangerous in this regard, because of the multiplicity of its lesions and their tendency to appear outside of the genital sphere. The frequency of syphilitic sores in the mouth is the most potent argument against the common drinking cup and common towel, both of which now fortunately belong to the past. The only thing in common use in cars which is liable to contamination with venereal discharges is the toilet seat. It should be of such form as to render genital contact easily avoidable; but whatever its form, common decency should impel everyone to avoid genital contact with the seat of a public toilet, and if that is done the danger of infection practically disappears. The actual sins of the public toilet may be great enough at the best, but the transmission of venereal diseases by them is probably very rare.

There are no laws or regulations which forbid venereally infected persons to use the ordinary means of travel, though the Interstate Quarantine Regulations provide for certain restrictions the principal object of which is the securing of continued treatment. In November, 1918, a section was added to the regulations requiring that persons afflicted with venereal diseases who wish to travel shall obtain a permit from the local health officer of the jurisdiction in which he resides, that the local health officer at destination shall be immediately notified, and that the patient shall report to the latter within one week after arrival. In the recent draft of the regulations the section reads as follows:

SEC. 8. *Travel of venereally infected persons.*—(*a*) Any person infected with syphilis, gonorrhea, or chancroid who wishes to engage in interstate travel must first obtain a permit, in writing, from the local health officer under whose jurisdiction he resides. This permit shall state that, in the opinion of the health officer, such travel is not dangerous to the public health.

(*b*) Any person infected with syphilis, gonorrhea, or chancroid who wishes to change his residence from one State to another must first obtain his release, in writing, from the local health officer. He shall inform the local health officer as to the place where he intends to reside and shall agree, in writing, to report in person to the proper health officer within one week after arrival at his new residence. It shall be the duty of the health officer who issues the release to promptly notify the health officer under whose jurisdiction the infected person is to enter, of its issue. This release shall contain the name and address of the infected person. The receiving health officer shall, in turn, report the arrival of the infected person to the health officer who issued his release and notify the State health officer of his State that a person infected with venereal disease has entered his jurisdiction.

(*c*) Any person infected with syphilis, gonorrhea, or chancroid, who wishes to engage in interstate travel or change his residence shall agree to continue treatment under the direction of a reputable physician, until the health officer, or his accredited representative, shall have complied with the State board of health requirements for release of venereally infected persons.

Suggested forms for permits and for the various notifications are appended to the regulations. Some of the States have similar requirements. There has been no considerable call for the notification forms, the use of which must be practically limited to those cases being treated in the free clinics of the States, but there have been numerous instances of quarantine and detention of persons who have ignored the regulations and have refused to act in accordance with the instructions of public health officials in the continuance of treatment. But whether strictly complied with or not, such regulations can not by any means do harm, and if accompanied by an intelligent and persistent campaign along the lines of sanitation and hygiene they may ultimately do much good. If to any extent whatever they induce the continuance of treatment, they are to that extent useful, and there is sufficient evidence that they have done so in many instances. At any rate, the educational campaign now being carried on throughout a large part of the world should go on and be increased, in the hope that it may eventually result in the successful, if long delayed, control of the venereal diseases.

6. MISCELLANEOUS DISEASES.

There have been considered in the foregoing groups all those infectious diseases which by reason of their frequency, their general distribution, or their danger of communication under the circumstances of travel are likely to give rise to passenger traffic problems. Other communicable diseases are rarely dealt with specifically by the laws or regulations concerning railway travel of the States, though many States have more or less drastic general restrictions covering all infectious diseases.[46] A few other specific diseases have, however, been included in certain official restrictions and deserve a word of comment.

The Interstate Quarantine Regulations include Rocky Mountain spotted fever and anthrax in the group to be controlled as are the sputum-borne diseases; that is, cases must be isolated in a separate compartment, be in charge of a skilled attendant, and the sputum and nasal discharges must be disinfected or destroyed. There will rarely be occasion for railway travel by cases of either of these diseases. The first is restricted to a relatively small area of the region that gives it its name, the cases are usually found among ranchmen or other rural inhabitants, are acute, of relatively short duration, and often fatal. Of anthrax we have very few cases anywhere, and those few are mostly among the industrial population of the cities and in easy reach of hospital care.

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[46] See page 10.

If cases of either of these diseases are transported, they should be isolated and personally attended, but the other restrictions applied by the Interstate Quarantine Regulations are hardly applicable, for the sputum is not the source of infection or the means by which the diseases are carried. Rocky Mountain spotted fever is an insect-borne disease. It is not transmitted by contact, and is therefore not contagious in the ordinary sense, and there are no infectious body wastes or discharges. The infection resides in the blood, and the disease is transmitted by the bite of a tick, just as plague is borne by the flea or yellow fever and malaria by mosquitoes. Regulations which do not recognize this fact will not be effective. Patients should be made tick-free; they will then be safe passengers, but otherwise they will not; and unless ticks are removed in a most painstaking manner, such patients should not be transported.

Anthrax, on the other hand, as we see it in human beings, is a disease in which the surface of the body is commonly the seat of open sores, the discharges from which contain the infecting organism. The infection gains entrance as a rule through cuts or abrasions of the skin or mucous membranes, causing first a local and then a general disease. Safeguarding measures should be directed to collecting and destroying the surface discharges rather than the sputum, though the latter may also be infectious if there are lesions of the mucous membranes and may need to be included. The anthrax bacillus is one of the most highly resistant of all known pathogenic organisms. It may live for a long time outside the body and is not readily destroyed by drying, heat, light, or chemical agents which readily destroy other disease-producing germs. If furnishings are contaminated by anthrax discharges they may remain infected indefinitely. The transporting of anthrax cases in railway passenger cars is therefore a doubtful practice under any circumstances, and if any regulations concerning it are deemed necessary they would probably best be simple prohibitive ones, as they are now in a few of the States.[47]

Glanders is also a rare disease which occasionally comes under the official ban to travel.[47] The prohibition is right, for the disease in man is highly infectious, is readily transmitted by contact, and is almost invariably fatal. But there are so few cases that the question of transportation almost never arises.

The regulations of Delaware include erysipelas and puerperal fever in the diseases forbidden to travel. These infections with the pus-producing organisms, while serious in themselves and dangerous enough to people with open wounds who may find themselves adjacent, as in surgical or maternity wards, are not likely to be dangerous to other travelers under the usual conditions of travel if reasonable precautions are taken, and there does not seem to be sufficient reason why they should not be transported where there is need of it. They should be isolated and personally attended, and discharges from their lesions should be disinfected or destroyed.

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[47] Delaware, New Jersey. May be carried in Delaware with the permission of the State board of health.

Why malaria, trichinosis, hydrophobia, "tuberculosis in any of its manifestations," or trachoma should be forbidden to enter the cars of common carriers, as they are in the State of New Jersey, is difficult to see. If malaria were a rare disease there might be reason to restrain its subjects; but where the disease exists at all it is frequently the case that a large proportion of the population is infected, and for all but the relatively brief period of the paroxysm of fever most of the cases go on about their affairs, so that restraint is not feasible. Nor is it necessary. Contact with the patient himself is without danger. The disease can be contracted only from the bite of the anopheles mosquito, at an interval of some days after it has become infected by biting a malaria patient. Where mosquitoes are allowed to breed freely, malaria is likely to be prevalent, and their elimination is the only preventive measure that has ever been found to be of any considerable value. There is of course good reason why malarious patients should not migrate into regions where the anopheles abound but where there is no malaria, for from such patients the disease may gain a foothold. But this has nothing to do with the danger of their riding in cars.

Hydrophobia and trichinosis can not possibly be dangerous to other travelers. Neither disease is transmitted directly from one person to another.

In the case of trachoma, an infectious disease of the eyes, there would be reason for excessive caution if the common towel were still in use; but with the abolition of that, the danger practically disappears under the ordinary conditions of travel. Eye to eye transfer of the virus, directly or through some indirect agency, is required for the infection to take place; and the common towel is practically the only means of bringing this about, at least on board a train. But aside from the danger that might arise, the trachomatous patient is neither sick nor ordinarly discoverable, and he will rarely be amenable to regulatory measures.

For those who are sick of the noncommunicable diseases the necessities in travel are only those which will give to them a reasonable degree of comfort and will not too greatly interfere with the comfort of other travelers. If the illness is so severe as to be entirely disabling, the patient should have a compartment to himself and be accompanied by an attendant, for there is no one in charge of regular railway travel who is either skilled enough, interested enough, or has time enough to attend to more than the simplest of sick people's wants. The noninfectious sick who are able to care for themselves should be allowed to travel as healthy people do.

CASES DISCOVERED EN ROUTE.

The suspicion or discovery of a case of one of the dangerous communicable diseases among railway passengers always gives rise to an uncomfortable situation for those in charge of the operation of trains, because of the possibility that train movement may be interfered with. One object to be attained in the handling of such cases is to limit interference with traffic and with the comfort and convenience of other passengers to the minimum consistent with the safety of the public health. The first essential is for the person in charge to get competent medical advice, so that he may know what his problem is. The railways generally have extensive medical organizations, and some member of the staff can usually be reached by wire without unreasonable delay. If there is space available in which isolation of the suspect can be carried out quietly, this should be done while medical aid is being awaited; but if much commotion is necessary things may be best let alone until final action can be taken.

The final disposition of such cases will always lie with the public health officials, and the most direct means possible of calling them into consulation should be utilized. The railroad surgeon may make the diagnosis, may institute isolation and provide for temporary care, but in all States and all communities the communicable diseases are subject to quarantine regulations which must be carried out under the supervision of a health officer. A reasonable attempt at providing proper care for an afflicted person is all that is demanded up to the time such as officer becomes available, but after that time his judgment must be followed and the case disposed of according to his orders.

Many of the States have provisions in their quarantine laws specifically relating to cases of infectious diseases discovered on railway trains in transit. The State board of health is usually given very broad powers in dealing with such cases. A common provision of the laws is to the effect that the car occupied by such a passenger may be detained on any siding, held in isolation, fumigated, disinfected, or otherwise disposed of under such rules as the board of health deems necessary under the circumstances. In some States the railway conductor who discovers or suspects that he is carrying an infectious passenger is required to notify by telegraph or telephone the nearest public-health officer and to take orders from him concerning the disposition of both the passenger and the car. In one State[48] the carrier is required to return the patient to the point of his departure, though no rules or regulations are provided governing the manner in which the return transportation is to be carried out so as to protect the public.

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[48] Nebraska.

The Standard Railway Sanitary Code and the Interstate Quarantine Regulations contain provisions giving definite instructions as to the method of procedure by the railway personnel when communicable diseases are discovered or suspected among railway travelers. The sections of the standard code dealing with the subject read as follows:

> SEC. 6. *Suspected cases.*—If a conductor or other person in charge of a railway train, car, or other conveyance, or an agent or other person in charge of a railway station, shall have any reason to suspect that a passenger or a person contemplating passage is afflicted with any of the diseases enumerated in sections 1, 3, and 4, he shall notify the nearest health officer, or company physician if the health officer is not available, by the quickest and most practicable means possible, of his suspicion; and said health officer or physician shall immediately proceed to the train, car, or other conveyance at the nearest possible point, or to the railway station, to determine whether such disease exists.
>
> SEC. 7. *Disposition.*—If the health officer or physician, as provided for in section 6, shall find any such person to be afflicted with any of the diseases enumerated in sections 1, 3, and 4, he shall remove such person from the station or conveyance, or shall isolate him and arrange for his removal at the nearest convenient point; shall treat the car or other conveyance as infected premises, allowing it to proceed to a convenient place for proper treatment if in his judgment consistent with the public welfare, in such case notifying the health officer in whose jurisdiction the place is located; and shall take such other measures as will protect the public health: *Provided*, That if not prohibited in sections 1 and 2 of these regulations the afflicted person so found may be allowed to continue his travel if arrangements are made to comply, and he does so comply, with the requirements of the section of these regulations pertaining to the disease with which he is afflicted.

The above-quoted regulations apply locally in the 20 States that have officially adopted the Standard Railway Sanitary Code, namely, Alabama, Florida, Georgia, Illinois, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia, West Virginia, Washington, and Wisconsin. In States where there are no specific regulations, those quoted furnish a safe guide to proper practice and may be followed with assurance that all reasonable requirements are being met.

The Interstate Quarantine Regulations, applying to all interstate traffic, are practically to the same effect as the Standard Railway Sanitary Code, though cast in a somewhat different form. While it is not stated, as it is in the Standard Code, that the patient may be allowed to proceed if he is able to comply with the regulations applying to his particular disease, this must be understood; otherwise the regulations concerning the transportation of particular diseases would have no meaning. Since both codes agree in all essential requirements pertaining to the transportation of the various diseases, the handling of the matter of continuance of the journey will be the same whether the journey is intrastate or interstate. The Interstate Quarantine Regulations read as follows:

> SEC. 9. *Sick passengers en route.*—In the event of the appearance of any disease mentioned in section 1, with the exception of tuberculosis and venereal diseases, in any person aboard any car, vessel, vehicle, or conveyance operating in interstate traffic, the common carrier shall at once isolate the sick person and remove him from the car, vessel, vehicle, or conveyance at the first convenient place at which reasonable provision may be had for the protection of the patient and the public health, and shall immediately notify the Surgeon General of the United States Public Health Service and the State and local health officer of the place at which the person was removed from such car, vessel, vehicle, or conveyance.
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> (*a*) In accordance with the foregoing paragraph, a yellow-fever case occurring en route shall be isolated in a compartment so screened as to prevent the entrance or exit of mosquitoes, or their access to the patient; and the patient shall not be disembarked in infectible territory unless thoroughly protected from mosquitoes, and unless permission for such disembarkation has been obtained from the State and local health officials having jurisdiction over the place of disembarkation.

CONVEYANCES VACATED BY INFECTED PERSONS.

The after care of premises vacated by cases of the communicable diseases has varied from time to time according to the prevailing belief as to the manner in which infections are commonly transmitted. It is not even now on an entirely satisfactory basis for all diseases, but as accurate knowledge of the modes of transmission of particular diseases has been acquired the details of preventing their spread have become more logical and more effective and the indications for the after care of quarters have become clearer. When we learned to a certainity that malaria and yellow fever are transmitted only by mosquitoes, it ceased to be necessary to expend efforts on sterilizing rugs and furniture; when it became apparent that most pathogenic bacteria have only a very short life outside of the body and that direct or indirect personal contact is the common means of transmitting the common infectious diseases, the after care of vacated quarters began to give way to destruction of dangerous discharges and excreta during the course of the illness.

Scarcely more than a decade ago terminal disinfection by means of fumigation was the rule after all infectious diseases; to neglect it was to indulge in criminal carelessness. When Chapin[49] first seriously questioned the usefulness of terminal fumigation, in an address before the American Medical Association in 1905, he aroused a storm of protest; but since that time the trend of thought has been gradually toward the acceptance of his view, until now there are few sanitarians who place any considerable value on terminal disinfection as a disease-preventing measure. Faith is pinned to rigid cleanliness during the course of the disease and to the immediate disinfection of discharges as they occur. Fumigation of vacated quarters has ceased to be a standard procedure in many of the larger cities and in some of the States, terminal cleansing taking its place; in some it has become entirely obsolete; and it has been found that subsequent cases do not occur more frequently in houses where fumigation is omitted than in those where it is carried out. The room itself is a very slight source of infection. This fact is so well established that the American Public Health Association[50] has gone on record against the necessity of terminal disinfection, other than that involved in thorough mechanical cleansing, after all the communicable diseases except cholera, plague, and smallpox.

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[49] Chapin, The Fetish of Disinfection, J. A. M. A., 1906, xlvii, 574.

These new interpretations apply of course to the care of railway cars that have carried infectious diseases. The first hygienic necessity is for rigid cleanliness and the disinfection of discharges while the patient is in transit, as has been provided for in regulations already discussed; the second is for thorough mechanical cleaning when the car is vacated and has reached its terminal. For the common infectious diseases no more is required to overcome the dangers of transmission, and no more is generally demanded by the rules of boards of health. But there are still many boards of both cities and States that require terminal disinfection after most of the communicable diseases, and practically all of them require it after smallpox and a few others. There has been included, therefore, in both the Standard Railway Sanitary Code and the Interstate Quarantine Regulations, which are practically identical on this point, a requirement for terminal disinfection after all the communicable diseases for which travel regulations are made except the venereal diseases and tuberculosis. The Interstate Quarantine Regulations read as follows:

> SEC. 10. *Conveyances vacated by infected persons.*—Immediately after vacation by a person having any of the diseases mentioned in section 1, with the exception of pulmonary tuberculosis and venereal diseases, any berth, compartment, or stateroom should be closed and not again occupied until properly cleaned and disinfected, and all bedding, blankets, and linen in any such space should be laundered or otherwise thoroughly cleaned and disinfected before being again used.
>
> (*a*) In regard to a yellow-fever case, the compartment vacated by the patient shall be fumigated immediately upon disembarkation of patient in such manner as to insure the complete destruction of all mosquitoes contained therein.

It is not necessary to go into the details of mechanical cleaning here. Soap and water and physical work are its elements, sunlight and air its accessories; and the qualifying adjective, thorough, should be always kept in mind. It is a common practice of the railroads to add one of the many coal-tar disinfectants to the wash water in car cleaning. In 1 or 2 per cent solution they have a considerable bactericidal efficiency, and may be considered as adding effectiveness to the renovating process. But this can not be considered as fulfilling the conditions of the regulation. There are some parts of the car, or some things in it, that can not very well be washed—window shades, carpets, the coverings of seats, and the mattresses and pillows of sleeping cars—and some other process must be employed. The common way of carrying out general disinfection is by means of fumigation with formaldehyde gas. That is what is contemplated by the regulation. It should be so understood.

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[50] Report of the Committee on Standard Methods for the Control of Communicable Diseases, U. S. Public Health Reports, October 12, 1917. Reprint No. 436.

In the treatment of all spaces where communicable disease patients have been, the value of sunlight as a bactericidal agent should always be kept in mind. Cars are fortunately rooms of many windows, and may often be flooded with sunlight while cleaning is going on. Advantage should be taken of this fact. Whenever possible, all movable things in the compartment should be taken out of the car where they may be better exposed. Upholstered seats, mattresses, pillows, and hangings should be placed in the sun for several hours, and should be turned over from time to time so that all sides may be equally affected.

Washable materials, such as blankets and the outer ticks of pillows (all sleeping-car pillows are supplied with double ticks), should be sent to the laundry for washing, where they will be rendered essentially sterile. All linen will be similarly treated as a matter of course, since there is no such thing as its repeated use in car service in this country.

It is not contemplated that the insect-borne diseases, plague, yellow fever, and typhus fever, will have occupied railway cars; they are not accepted for transportation under any circumstances. It has occasionally happened, however, that one of these diseases has developed in a passenger en route. The occurrence of such cases is so exceedingly rare that general rules can scarcely be made to cover the situation, which must be dealt with according to local conditions. Attention will, of course, be directed to destroying the insects concerned, if these by any chance have accompanied the patient. Formaldehyde gas will not kill them. Sulphur will do it, if burned in sufficient quantity, but it has the disadvantage of being destructive to the color of fabrics and corrosive to metals. Thorough spraying with an insecticide solution, of which the market affords a great number, will be effective if properly done. Without doubt the best insecticide is hydrocyanic acid gas, but it is so exceedingly poisonous to human beings that it can be used only under the direct supervision of experts; and even then fatal accidents may occur. In any of these cases the local board of health will, however, usually take charge; and anything they order must be done, even to the destruction by fire of bedding and furnishings, as has sometimes been demanded. If the expense is considerable, it is so seldom incurred as to be of little consequence.

APPENDIX.

INTERSTATE QUARANTINE REGULATIONS.

The Interstate Quarantine Regulations of the United States are promulgated by the Secretary of the Treasury on the advice of the United States Public Health Servic under powers conferred by an act of Congress approved February 15, 1893. They hav the force of law and penalties may be imposed for noncompliance. They apply t all traffic passing from one State into another.

The Interstate Quarantine Regulations now in force are the product of gradua growth by addition and revision through a long period of years. They consist of 3 sections, divided as follows: (I) Transportation of persons or things infected wit communicable diseases; sections 1 to 18. (II) Water supplies; sections 19 and 2 (III) Sanitation of cars and vessels; sections 21 to 29. (IV) Sanitation of stations an camps; sections 30 and 31.

Only the first 10 sections of the regulations apply to the transportation of person infected with communicable diseases. They are as follow:

SEC. 1. *Quarantinable diseases.*—For the purpose of interstate quarantine the following diseases shall be regarded as contagious and infectious diseases within th meaning of section 3 of the act approved February 15, 1893: Plague, cholera, smallpox typhus fever, yellow fever, typhoid fever, paratyphoid, dysentery, pulmonary tuberculosis, leprosy, scarlet fever, diphtheria, measles, whooping cough, epidemic cerebrospinal meningitis, anterior poliomyelitis, Rocky Mountain spotted or tick fever syphilis, gonorrhea, chancroid, anthrax, influenza, pneumonia, epidemic encephalitis septic sore throat, rubella, and chicken pox.

SEC. 2. *Quarantinable persons or things.*—Any person or thing, either living or dead which has been unduly exposed to or in intimate contact with or is infected wit any of the diseases enumerated in section 1, except as otherwise provided in thes regulations, shall be regarded as contagious or infectious until the contrary has bee proved, and if found in any car, vessel, vehicle, or conveyance undergoing interstat transportation, shall be subjected to such inspection, disinfection, or other measure as may be necessary to prevent the spread of the infection from them.

SEC. 3. *Observance of travel regulations.*—Common carriers shall not knowingl accept for transportation from one State or Territory or the District of Columbia int another State of Territory or the District of Columbia any person suffering from any the diseases mentioned in section 1, except as hereinafter provided; and no perso knowing that he is in the communicable stage of any of the diseases enumerated i section 1 shall travel on any car, vessel, vehicle, or other conveyance engaging i interstate traffic, except as hereinafter provided, nor shall any parent, guardia physician, nurse, or other person allow or procure such transportation for any mino ward, patient, or other person under his charge.

SEC. 4. *Persons prohibited from travel.*—No person infected with plague, choler smallpox, yellow fever, or typhus fever shall be received by common carriers, the agents, or employees, upon any vessel, car, vehicle, or conveyance operating i interstate traffic.

SEC. 5. *Travel of lepers.*—Common carriers shall not accept for transportation transport in interstate traffic any person known by them to be afflicted with lepros nor shall any person so afflicted accept such transportation except as hereinaft provided.

(*a*) A person afflicted with leprosy shall be permitted to accept transportation upon presentation of permits from the Surgeon General of the United States Public Health Service, or his accredited representative, and from the health authorities of the States, Territories, or District of Columbia to and from which he intends to travel, stating that such person may be received under such restrictions, which shall be specified in each instance, as will prevent the spread of the disease, provided such person shall have agreed in writing to comply, and does so comply, with the restrictions as specified.

(*b*) Any person who presents symptoms of leprosy, and who is traveling or who has left the State where he resides in violation of the above regulations, shall be detained: and, if proved to be a leper, shall be returned to such State or removed to such Federal station as the Secretary of the Treasury may designate, and the proper health authorities notified.

SEC. 6. *Travel of diseased persons.*—Except as prohibited in section 3 and except leprosy, pulmonary tuberculosis, and venereal diseases provided for in other paragraphs of these regulations, common carriers shall not receive upon any car, vessel, or conveyance operating in interstate traffic any person known by them to be afflicted with any of the diseases enumerated in section 1, or any person known to be a carrier of these diseases, unless removal and entrance permits have been granted by the State or local health officers at the places of departure and arrival, and unless such person is placed in a compartment separate from other passengers, is accompanied by a properly qualified nurse or other attendant, and unless such nurse or attendant has pledged himself or herself in writing to the common carrier to comply with the following regulations, and does so comply while in transit:

(*a*) Communication with the compartment within which the patient is traveling shall be restricted to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient en route shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All sputum and nasal discharges from the patient shall be received in gauze or paper, which shall be deposited in a paper bag or in a closed vessel and shall be destroyed by burning or disinfected by immersing for at least one hour in a 5 per cent solution of carbolic acid or other solution of equivalent disinfecting value.

(*d*) Said nurse or attendant shall, after performing any service to the patient, at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

(*e*) In the case of a person afflicted with typhoid fever, paratyphoid fever, or dysentery the nurse or attendant shall pledge himself or herself in writing to the common carrier to comply with the following regulations while in transit, in addition to (*a*), (*b*), (*c*), and (*d*) of this section:

1. All urine and feces of the patient shall be received into a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value, placed in a covered vessel, thoroughly mixed, and allowed to stand for at least two hours after the last addition thereto before being burned, destroyed, or emptied.

2. A sheet of rubber or other impervious material shall be carried and shall be spread between the sheet and the mattress of any bed that may be used by the patient while in transit.

3. Said nurse or attendant shall use all necessary precautions to prevent the access of flies to the patient or his discharges.

4. *Provided*, That if a person with typhoid, paratyphoid, or dysentry is presented at a railway station in ignorance of these regulations and his transportation is necessary as a life-saving or safeguarding measure, an emergency may be declared, and the

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SEC. 2. *Quarantinable persons or things.*—Any person or thing, either living or dead, which has been unduly exposed to or in intimate contact with or is infected with any of the diseases enumerated in section 1, except as otherwise provided in these regulations, shall be regarded as contagious or infectious until the contrary has been proved, and if found in any car, vessel, vehicle, or conveyance undergoing interstate transportation, shall be subjected to such inspection, disinfection, or other measures as may be necessary to prevent the spread of the infection from them.

SEC. 3. *Observance of travel regulations.*—Common carriers shall not knowingly accept for transportation from one State or Territory or the District of Columbia into another State of Territory or the District of Columbia any person suffering from any of the diseases mentioned in section 1, except as hereinafter provided; and no person knowing that he is in the communicable stage of any of the diseases enumerated in section 1 shall travel on any car, vessel, vehicle, or other conveyance engaging in interstate traffic, except as hereinafter provided, nor shall any parent, guardian, physician, nurse, or other person allow or procure such transportation for any minor, ward, patient, or other person under his charge.

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SEC. 5. *Travel of lepers.*—Common carriers shall not accept for transportation or transport in interstate traffic any person known by them to be afflicted with leprosy, nor shall any person so afflicted accept such transportation except as hereinafter provided.

(*a*) A person afflicted with leprosy shall be permitted to accept transportation upon presentation of permits from the Surgeon General of the United States Public Health Service, or his accredited representative, and from the health authorities of the States, Territories, or District of Columbia to and from which he intends to travel, stating that such person may be received under such restrictions, which shall be specified in each instance, as will prevent the spread of the disease, provided such person shall have agreed in writing to comply, and does so comply, with the restrictions as specified.

(*b*) Any person who presents symptoms of leprosy, and who is traveling or who has left the State where he resides in violation of the above regulations, shall be detained: and, if proved to be a leper, shall be returned to such State or removed to such Federal station as the Secretary of the Treasury may designate, and the proper health authorities notified.

SEC. 6. *Travel of diseased persons.*—Except as prohibited in section 3 and except leprosy, pulmonary tuberculosis, and venereal diseases provided for in other paragraphs of these regulations, common carriers shall not receive upon any car, vessel, or conveyance operating in interstate traffic any person known by them to be afflicted with any of the diseases enumerated in section 1, or any person known to be a carrier of these diseases, unless removal and entrance permits have been granted by the State or local health officers at the places of departure and arrival, and unless such person is placed in a compartment separate from other passengers, is accompanied by a properly qualified nurse or other attendant, and unless such nurse or attendant has pledged himself or herself in writing to the common carrier to comply with the following regulations, and does so comply while in transit:

(*a*) Communication with the compartment within which the patient is traveling shall be restricted to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient en route shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All sputum and nasal discharges from the patient shall be received in gauze or paper, which shall be deposited in a paper bag or in a closed vessel and shall be destroyed by burning or disinfected by immersing for at least one hour in a 5 per cent solution of carbolic acid or other solution of equivalent disinfecting value.

(*d*) Said nurse or attendant shall, after performing any service to the patient, at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

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1. All urine and feces of the patient shall be received into a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value, placed in a covered vessel, thoroughly mixed, and allowed to stand for at least two hours after the last addition thereto before being burned, destroyed, or emptied.

2. A sheet of rubber or other impervious material shall be carried and shall be spread between the sheet and the mattress of any bed that may be used by the patient while in transit.

3. Said nurse or attendant shall use all necessary precautions to prevent the access of flies to the patient or his discharges.

4. *Provided*, That if a person with typhoid, paratyphoid, or dysentry is presented at a railway station in ignorance of these regulations and his transportation is necessary as a life-saving or safeguarding measure, an emergency may be declared, and the

patient may be carried a reasonable distance in a baggage car if accompanied by an attendant responsible for his care and removal: *Provided also*, That regulations (*a*), (*b*), (*c*), (*d*), and (*e*) of this section shall be complied with in so far as the circumstances will allow, and that all bedding, clothing, rags, or cloths used by the patient shall be removed with him: *And provided further*, That any parts of the car which have become contaminated by any discharges of the patient shall be disinfected as soon as practicable, but not later than the end of the run, by washing with a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

SEC. 7. *Travel of tuberculous persons.*—Common carriers, their agents or employees, shall not receive for interstate transportation any person known by them to be afflicted with pulmonary tuberculosis in a communicable stage unless said person is provided with (*a*) a sputum cup made of impervious material and so constructed as to admit of being tightly closed when not in use; (*b*) a sufficient supply of gauze, papers, or similar articles of the proper size to cover the mouth and nose while coughing or sneezing; (*c*) a heavy paper bag or other tight container for receiving the soiled gauze, paper, or similar articles; and unless such person shall obligate himself to use the articles provided for in the manner intended, and to destroy said articles by burning or to disinfect them by immersing for at least one hour in a 5 per cent solution of carbolic acid or other solution of equivalent disinfecting value in a covered vessel.

SEC. 8. *Travel of venereally infected persons.*—(*a*) Any person infected with syphilis, gonorrhea, or chancroid who wishes to engage in interstate travel must first obtain a permit, in writing, from the local health officer under whose jurisdiction he resides. This permit shall state that, in the opinion of the health officer, such travel is not dangerous to the public health.

(*b*) Any person infected with syphilis, gonorrhea, or chancroid who wishes to change his residence from one State to another must first obtain his release, in writing, from the local health officer. He shall inform the local health officer as to the place where he intends to reside, and shall agree, in writing, to report in person to the proper health officer within one week after arrival at his new residence. It shall be the duty of the health officer who issues the release to promptly notify the health officer under whose jurisdiction the infected person is to enter of its issue. This release shall contain the name and address of the infected person. The receiving health officer shall, in turn, report the arrival of the infected person to the health officer who issued his release and notify the State health officer of his State that a person infected with venereal disease has entered his jurisdiction.

(*c*) Any person infected with syphilis, gonorrhea, or chancroid who wishes to engage in interstate travel or change his residence shall agree to continue treatment under the direction of a reputable physician until the health officer, or his accredited representative, shall have complied with the State board of health requirements for release of venerally infected persons.

SEC. 9. *Sick passenger en route.*—In the event of the appearance of any disease mentioned in section 1, with the exception of tuberculosis and venereal diseases, in any person aboard any car, vessel, vehicle, or conveyance operating in interstate traffic, the common carrier shall at once isolate the sick person and remove him from the car, vessel, vehicle, or conveyance at the first convenient place at which reasonable provision may be had for the protection of the patient and the public health, and shall immediately notify the Surgeon General of the United States Public Health Service and the State and local health officer of the place at which the person was removed from such car, vessel, vehicle, or conveyance.

(*a*) In accordance with the foregoing paragraph, a yellow-fever case occurring en route shall be isolated in a compartment so screened as to prevent the entrance or exit of mosquitoes, or their access to the patient; and the patient shall not be disembarked in infectible territory unless thoroughly protected from mosquitoes, and unless permission for such disembarkation has been obtained from the State and local health officials having jurisdiction over the place of disembarkation.

SEC. 10. *Conveyances vacated by infected persons.*—Immediately after vacation by a person having any of the diseases mentioned in section 1, with the exception of pulmonary tuberculosis and venereal diseases, any berth, compartment, or stateroom should be closed and not again occupied until properly cleaned and disinfected. and all bedding, blankets, and linen in any such space should be laundered or otherwise thoroughly cleaned and disinfected before being again used.

(*a*) In regard to a yellow-fever case, the compartment vacated by the patient shall be fumigated immediately upon disembarkation of patient in such manner as to insure the complete destruction of all mosquitoes contained therein.

STANDARD RAILWAY SANITARY CODE.

What is now known as the Standard Railway Sanitary Code was originally prepared, under the simpler title of a railway sanitary code, by the committee on health and medical relief for the United States Railroad Administration. It was submitted to the Surgeon General of the United States Public Health Service, and such changes were made as were necessary to bring it into accord with the Interstate Quarantine Regulations as they then were, and was then distributed by the Director General of Railroads to the various Federal managers as a guide to standard practice. When the committee on health and medical relief was dissolved, early in 1920, the code was presented to the Conference of State and Provincial Health Authorities of North America, which, after some minor amendments, adopted it at the annual meeting in May, 1920, under its present title, and recommended that the several States adopt and promulgate it as a part of their sanitary regulations.

The purpose of this action by the Conference of State Health Authorities was to replace with a uniform code the diverse and often inconsistent regulations of the States for the sanitary control of railway traffic and to harmonize the intrastate with the interstate regulations. In accordance with the recommendation the code has been adopted and is now in effect in the following 20 States: Alabama, Florida, Georgia, Illinois, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, North Dakota, South Carolina, Tennessee, Virginia, Washington, West Virginia, Wisconsin.

The Standard Railway Sanitary Code consists of 91 sections, divided as follows: (I) Transportation of persons having communicable diseases; sections 1 to 10. (II) Water and ice supplies; sections 11 to 15. (III) Cleaning and disinfection of cars; sections 16 to 20. (IV) Sanitation of cars in service; sections 21 to 43. (V) Sanitation of railway stations; sections 44 to 72. (VI) Sanitation of construction camps; sections 73 to 91.

The first 10 sections, which apply to the transportation of persons having communicable diseases, are as follow:

SECTION 1. *Persons not allowed to travel.*—No person knowing or suspecting himself to be afflicted with plague, cholera, smallpox, typhus fever, or yellow fever shall apply for, procure, or accept transportation in any railway train, car, or other conveyance of a common carrier, nor shall any person apply for, procure, or accept such transportation for any minor, ward, patient, or other person under his charge if known or suspected to be so afflicted.

SEC. 2. *Persons not accepted for travel.*—Common carriers shall not accept for transportation in any railway train, car, or other conveyance any person known by them to be afflicted with any of the diseases enumerated in section 1.

SEC. 3. *Restricted travel.*—Common carriers shall not accept for transportation on any railway train, car, or other conveyance any person known by them to be afflicted with diphtheria, measles, scarlet fever, epidemic cerebrospinal meningitis, anterior poliomyelitis, mumps, whooping cough, influenza, pneumonia, epidemic encephalitis, septic sore throat, rubella, or chicken pox, or any person known to be a carrier of these diseases, unless such person is placed in a compartment separate from other passengers, is accompanied by a properly qualified nurse or other attendant, and unless such nurse or attendant shall agree to comply and does so comply with the following regulations:

(*a*) Communication with the compartment in which the patient is traveling shall be restricted to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All sputum and nasal discharges from the patient shall be received in gauze or paper, which shall be deposited in a paper bag or in a closed vessel and shall be destroyed by burning.

(*d*) Said nurse or attendant shall, after performing any service to the patient, at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

SEC. 4. *Typhoid and dysentery.*—Common carriers shall not accept for transportation on any railway train, car, or other conveyance any person known by them to be afflicted with typhoid fever, paratyphoid fever, or dysentery, unless said person is placed in a compartment separate from other passengers, is accompanied by a properly qualified nurse or other attendant, and unless said nurse or attendant shall agree to comply and does so comply with the following regulations:

(*a*) Communication with the compartment in which the patient is traveling shall be limited to the minimum consistent with the proper care and safety of the patient.

(*b*) All dishes and utensils used by the patient shall be placed in a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value for at least one hour after they have been used and before being allowed to leave the compartment.

(*c*) All urine and feces of the patient shall be received into a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value, placed in a covered vessel, thoroughly mixed, and allowed to stand for at least two hours after the last addition thereto before being emptied.

(*d*) A sheet of rubber or other impervious material shall be carried and shall be spread between the sheet and the mattress of any bed that may be used by the patient while in transit.

(*e*) Said nurse or attendant shall use all necessary precautions to prevent the access of flies to the patient or his discharges, and after performing any service to the patient shall at once cleanse the hands by washing them in a 2 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

(*f*) *Provided,* That if a person with typhoid or dysentery is presented at a railway station in ignorance of these regulations and his transportation is necessary as a lifesaving or safeguarding measure, an emergency may be declared and the patient may be carried a reasonable distance in a baggage car if accompanied by an attendant responsible for his care and removal: *Provided also,* That regulations (*a*), (*b*), (*c*), (*d*), and (*e*) of this section shall be complied with in so far as the circumstances will allow, and that all bedding, clothing, rags, or cloths used by the patient shall be removed with him: *And provided further,* That any parts of the car which have become contaminated by any discharges of the patient shall be disinfected as soon as practicable, but not later than the end of the run, by washing with a 5 per cent solution of carbolic acid or other fluid of equivalent disinfecting value.

SEC. 5. *Restricted application for transportation.*—No person knowing or suspecting himself to be afflicted with any of the diseases mentioned in sections 3 and 4 shall apply for, procure, or accept transportation in any railway train, car, or other conveyance of a common carrier, nor shall any person apply for, procure, or accept such transportation for any minor, ward, patient, or other person under his charge if known or suspected to be so afflicted unless he shall have agreed to and made all necessary arrangements for complying, and does so comply, with the regulations set forth in said sections 3 and 4.

SEC. 6. *Suspected cases.*—If a conductor or other person in charge of a railway train, car, or other conveyance of a common carrier, or an agent or other person in charge of a railway station, shall have any reason to suspect that a passenger or a person contemplating passage is afflicted with any of the diseases enumerated in sections 1, 3, and 4, he shall notify the nearest health officer, or company physician if the health officer is not available, by the quickest and most practicable means possible, of his suspicion; and said health officer or physician shall immediately proceed to the train, car, or other conveyance at the nearest possible point, or to the railway station, to determine whether such disease exists.

SEC. 7. *Disposition.*—If the health officer or physician, as provided for in section 6, shall find any such person to be afflicted with any of the diseases enumerated in sections 1, 3 and 4, he shall remove such person from the station or conveyance, or shall isolate him and arrange for his removal at the nearest convenient point; shall treat the car or other conveyance as infected premises, allowing it to proceed to a convenient place for proper treatment if in his judgment consistent with the public welfare, in such case notifying the health officer in whose jurisdiction the place is located; and shall take such other measures as will protect the public health: *Provided,* That if not prohibited in sections 1 and 2 of these regulations the afflicted person so found may be allowed to continue his travel if arrangements are made to comply, and he does so comply, with the requirements of the section of these regulations pertaining to the disease with which he is afflicted.

SEC. 8. *Leprosy.*—Common carriers shall not accept for transportation nor transport in any railway train, car, or other conveyance any person known by them to be afflicted with leprosy, unless such person presents permits from the Surgeon General of the United States Public Health Service or his accredited representative, and from the State department of health of the States from which and to which he is traveling, stating that such person may be received under such restrictions as will prevent the spread of the disease, and said restrictions shall be specified in each instance; and no person knowing or suspecting himself to be afflicted with leprosy, nor any person acting for him, shall apply for, procure, or accept transportation from any common carrier unless such permits have been received and are presented, and unless the person so afflicted agrees to comply and does so comply with the restrictions ordered. If any agent of a common carrier shall suspect that any person in a train, car, or other conveyance, or at a railway station, is afflicted with leprosy, he shall proceed as directed in the case of other suspected diseases in sections 6 and 7 of these regulations.

SEC. 9. *Pulmonary tuberculosis.*—Common carriers shall not accept for transportation any person known by them to be afflicted with pulmonary tuberculosis in a communicable stage unless said person is provided with (*a*) a sputum cup made of impervious material and so constructed as to admit of being tightly closed when not in use, (*b*) a sufficient supply of gauze, papers, or similiar articles of the proper size to cover the mouth and nose while coughing or sneezing, (*c*) a heavy paper bag or other tight container for receiving the soiled gauze, paper, or similar articles; and unless such person shall obligate himself to use the articles provided for in the manner intended,

FURTHER STATISTICS OF LEPROSY IN HAWAII.

In Public Health Bulletin No. 33 (1910) Brinckerhoff and Reinecke presented the available statistics of leprosy in the Territory of Hawaii up to the end of 1908, and in Public Health Bulletin No. 66 (1914) McCoy gave further statistics up to the end of 1913. In this paper it is desired to record similar data up to the end of 1921. In another paper, statistics of cases of leprosy that have been allowed to leave segregation on parole will be recorded.

The paroling of apparently arrested cases of leprosy was begun in 1912. Some of these cases have suffered a relapse, and upon returning to segregation such patients have been taken up as new admissions. As a result, the gross figures require the deduction of these cases in order to represent the strictly new cases of leprosy apprehended.

In this paper the term "apprehended," does not necessarily mean arrest by process of law. It is used to designate all who have entered segregation. It should be stated here that in recent years some lepers have voluntarily entered segregation in hopes of having their disease arrested by proper treatment.

It is probable that there are errors in the figures given herein, but it is not believed that they are sufficient to impair their value to any great extent. The reliability of the data may be questionable but they are the best that can be obtained. A considerable portion of the data is based upon the statements of the patients or their relatives. Conditions influencing the information given in the tables will be discussed when considering the statistics given.

In order to give the reader a general view of the history of leprosy in Hawaii, the number of lepers apprehended in each year from 1866 to 1913, given in McCoy's paper, has been repeated here and to this the years 1914 to 1921 have been added.

TABLE 1.—*Total number of new cases.*

Year.	New cases.	Year.	New cases.	Year.	New cases.	Year.	New cases.
1866	141	1879	82	1892	109	1905	90
1867	57	1880	34	1893	210	1906	54
1868	76	1881	195	1894	137	1907	94
1869	73	1882	70	1895	106	1908	23
1870	31	1883	301	1896	147	1909	66
1871	128	1884	108	1897	126	1910	47
1872	69	1885	103	1898	80	1911	109
1873	295	1886	42	1899	58	1912	138
1874	53	1887	220	1900	102	1913	49
1875	128	1888	558	1901	86	1914	55
1876	57	1889	306	1902	87	1915	75
1877	110	1890	184	1903	121		
1878	136	1891	142	1904	96		

TABLE 1.—*Total number of new cases*—Continued.

Year.	New cases.	Readmissions.	Total admissions.	Year.	New cases.	Readmissions.	Total admissions.
1916	71	1	72	1919	98	2	100
1917	76	3	79	1920	98	4	102
1918	92	1	93	1921	100	18	118

NOTE.—Two paroled cases were readmitted without assignment of a new consecutive number, increasing the total number of readmissions to 31.

From Table 1 it is seen that the number of lepers entering segregation since 1913 has gradually increased, so that in 1921 it was double the number for 1913. Furthermore, considering the past 20 years by 5-year periods, we find that the last 5 years exceed the other periods, the totals, by 5-year periods, beginning with 1902, being 448, 339, 388, and 464, respectively. A part of the increase in the recent years may be due to the voluntary surrender of lepers, since it has become known that it is possible that the disease may be arrested by treatment and that segregation is not necessarily of lifelong duration.

TABLE 2.—*Nationality of lepers apprehended.*

Year.	Hawaiian.	Part Hawaiian.	Japanese.	Portuguese.	Filipino.	Korean.	Chinese.	European, other than Portuguese.	Porto Rican.	American.	Other Pacific Islanders.	Total.
1914	32	10	4	3	......	2	1	2	......	1	......	55
1915	52	14	2	4	......	1	......	1	......	1	......	75
1916	37	15	3	6	5	1	2	2	......	......	......	71
1917	35	15	3	7	5	3	5	2	1	......	......	76
1918	47	23	4	7	4	1	5	......	1	......	......	92
1919	63	15	6	2	6	2	......	......	3	......	1	98
1920	53	16	11	8	5	2	......	2	......	1	......	98
1921	43	22	13	6	5	3	......	2	2	3	1	100
Total	362	130	46	43	30	15	13	11	7	6	2	665

Table 2 aims to give the nationality, rather than the birthplace, of lepers segregated. A child born in Hawaii of American parents is recorded as American. Hawaiian applies only to the race which originally inhabited these islands. Part Hawaiian includes all racial mixtures in which any Hawaiian blood is present.

TABLE 3.—*Incidence by nationality.*

Nationality.	Population, census of 1920.	Lepers, 1914–1921.	Average annual incidence per 1,000.
Hawaiian	23,723	362	1.91
Part Hawaiian	18,027	130	.90
Japanese	109,274	46	.05
Portuguese	27,002	43	.21
Filipino	21,031	30	.18
Korean	4,950	15	.38
Chinese	23,507	13	.07
Caucasians other than Portuguese	22,138	17	.096
Porto Ricans	5,602	7	.16
Negro and others	658	2	.38
Total	255,912	655	.32

Table 3 shows the incidence of leprosy by nationalities during the eight years 1914 to 1921, based upon the figures of the census of 1920. The average annual incidence for this period has been 0.32 per 1,000. For the period 1901 to 1913, covered by McCoy's paper, the incidence, based on the census of 1910, was 0.42 per 1,000. Therefore, we find that the incidence rate of leprosy has decreased, though the average number of lepers segregated each year has increased. It is realized that this comparison is not very accurate by reason of the different number of years considered in each group, all rates being based upon the census falling within each period. However, considering the last two decades only, we find that for the 10 years 1912 to 1921 there were 852 lepers segregated, or an average annual incidence of 0.33 per 1,000, based on the census of 1920. For the 10 years 1902 to 1911 there were 873 lepers apprehended, which gives an average annual incidence rate of 0.45 per 1,000, based on the census of 1910. While this computation is not ideal, in that it is based on the population of a single year near the end of the decade, the same criticism applies equally in both periods under consideration.

These figures indicate that the incidence of leprosy in Hawaii is gradually lessening, and in view of the larger number of voluntary surrenders of lepers in the past three years, which would tend to maintain the rate at its former level, it is especially gratifying to the health authorities to see a decrease in incidence, even though it be small. In Table 3, Europeans and Americans are considered together to conform to the census designation "Caucasion other than Portuguese."

In McCoy's paper he states that "it sometimes happens that when leprosy is diagnosed in a foreigner, arrangements are made for returning the patient to his native land." While this would probably hold true for the first half of the period 1914 to 1921, in the latter half it does not, as the foreigner prefers to stay here in order to obtain the benefit of treatment which he may not be able to obtain in his fatherland. This also would tend to keep the incidence rate at a higher figure.

TABLE 4.—*Incidence by sex and age groups.*

Age group......	1 to 5 years.		6 to 10 years.		11 to 15 years.		16 to 20 years.		21 to 25 years.		26 to 30 years.		31 to 35 years.		36 to 40 years.		41 to 45 years.		46 to 50 years.	
Sex..........	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.		F.
1914..........	....	....	....	....	6	1	4	10	9	6	2	1	4	2	3	....	....	1	4	....
1915..........	....	....	....	2	8	12	3	7	5	3	10	3	4	1	5	1	5	2	1	....
1916..........	....	1	....	3	7	6	3	6	15	6	7	1	3	2	....	1	2	1	1	....
1917..........	....	....	2	3	8	1	8	4	10	....	8	2	5	1	4	1	5	3	2	4
1918..........	....	....	1	1	12	7	8	8	8	4	6	9	5	1	6	2	5	....	1	....
1919..........	....	....	3	4	9	5	15	5	10	6	5	6	4	1	9	1	2	1	3	2
1920..........	....	1	3	2	14	9	10	9	8	4	7	2	6	1	3	2	2	....	4	1
1921..........	....	....	3	6	7	12	3	6	8	9	5	4	4	6	4	....	5	4	5	....
Total....	....	2	12	21	71	53	54	55	73	38	50	28	35	15	34	8	26	12	21	7

TABLE 4.—*Incidence by sex and age groups*—Continued.

Age group	51 to 55 years.		56 to 60 years.		61 to 65 years.		66 to 70 years.		71 to 75 years.		76 to 80 years.		Not stated.		Total.		Grand totals year.
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1914	....	....	....	....	1	1	....	....	....	....	....	....	....	....	33	32	55
1915	....	1	....	....	....	....	1	....	....	....	....	....	1	....	43	32	75
1916	....	1	5	....	....	....	....	....	....	....	....	....	....	....	43	28	71
1917	1	....	1	....	1	....	1	....	1	....	....	....	....	....	57	19	76
1918	3	1	2	1	1	....	....	....	....	....	....	....	....	....	58	34	92
[illegible]	2	....	3	....	....	....	....	1	....	....	....	....	....	1	65	33	98
[illegible]	4	1	3	....	....	1	1	....	....	....	....	....	....	....	65	33	98
[illegible]	....	1	3	....	2	....	1	....	....	1	1	....	....	....	51	49	100
Total	10	5	17	1	5	2	4	1	1	1	1	....	1	1	415	250	665

Table 4 shows the incidence of leprosy in the two sexes and in different age groups, the age being that at which they entered segregation. The incidence, according to sex, has continued, as in previous years, at nearly 2 males to 1 female, though the year 1921 shows almost equal distribution between the sexes. In the age groups the females are more numerous in the age groups of 1 to 5 and 6 to 10 years, while in McCoy's paper the males predominated in the latter group. One does not usually think of leprosy as a disease of childhood or adolescence, but Table 3 shows that, for the period 1914 to 1921, 40 per cent of the lepers in Hawaii entered segregation before they reached 21 years of age, another 36 per cent entered between the ages of 21 and 36, leaving 24 per cent for what is usually considered as the last half of the allotted "threescore and ten years" of life.

TABLE 5.—*Civil state of lepers entering segregation.*

Year.	Married.	Single.	Widow or widower.	Divorced.	No information.	Total.
1914	26	28	....	....	1	55
1915	32	40	2	....	1	75
1916	26	43	2	....	....	71
1917	34	42	....	....	....	76
1918	32	55	4	1	....	92
1919	34	60	3	1	....	98
1920	23	68	5	1	1	98
1921	32	63	5	....	....	100
Total	239	399	21	3	3	665

The civil state of lepers entering segregation in the period 1914 to 1921 is shown in Table 5.

TABLE 6.—*Occupation.*

Occupation.	1914	1915	1916	1917	1918	1919	1920	1921	Total.
Barber				1					1
Carpenter		2	1	2		2			7
Chauffeur and teamster		4	2	1	1	4	4	4	20
Clerk and storekeeper			1	1	3		4	1	10
Cooper								1	1
Cowboy	2	1		1		1		1	6
Electrician		2	1		1				4
Engineer			1				1		2
Factory employee		1	1	1					3
Farmer and dairyman	2	1	1			8	5	4	21
Fisherman	1	1	1	1	2	1			7
Foreman	1	1		1	1				4
Gardener				2					2
House servant	1	3		1			1	1	7
Housewife	12	8	7	13	14	14	10	20	98
Inmate of industrial school		3		1	1	2	4	1	12
Janitor and sexton	1	1					1		3
Jockey							1		1
Laborers	16	12	24	21	25	18	18	25	159
Laundry worker	2						1		3
Longshoreman and stevedore		2		1	2	1		1	7
Machinist and mechanic		1			1	1	1		4
Moving picture operator					1				1
Painter		1		1	1				3
Printer				1					1
Policeman					2		1		3
Railroad employee	2			2	1	2			7
Seaman		2	2	1			1	1	7
Student and school child	11	12	13	15	7	6	14	15	93
Soldiers					1	1			2
Taro planter	1		1						2
Teacher		1							1
Telephone operator					1			1	2
No occupation, or none given	3	16	15	8	27	37	30	24	160
Total	55	75	71	76	92	98	98	100	665

Table 6 shows the occupation of lepers at the time they entered segregation.

TABLE 7.—*Association with lepers before segregation.*

Year.	Father.	Mother.	Grandparent.	Grandchild.	Sister or brother.	Son or daughter.	Uncle or aunt.	Nephew or niece.	Husband or wife.	Brother-in-law or sister-in-law.	Cousin.	Friend.	Kokua.	No association admitted.	Total.	Number of lepers in the family.								
																1	2	3	4	5	6	7	8	9
1914	...	...	...	...	7	1	2	1	1	....	1	7	...	35	55	46	6	3	...	...	...	...	...	...
1915	3	4	1	...	14	1	6	...	1	....	2	10	2	31	75	52	17	4	2	...	...	...	...	...
1916	4	2	2	...	12	1	2	...	1	....	3	2	...	42	71	51	13	6	1	...	...	...	...	...
1917	5	5	5	1	4	1	6	...	...	2	2	3	...	42	76	61	13	2	...	...	...	...	...	...
1918	3	4	1	...	13	1	12	1	...	....	5	2	1	49	92	71	14	5	1	...	1	...	...	...
1919	8	5	4	...	26	...	11	1	...	2	4	...	2	35	98	59	27	7	5	...	...	...	...	...
1920	5	5	3	1	16	3	14	2	...	2	6	1	1	39	98	69	26	3	...	...	...	...	...	...
1921	11	3	3	1	18	5	3	1	1	1	5	1	1	46	100	62	26	9	2	...	...	...	...	1
Total	39	28	19	3	110	13	56	6	4	7	28	26	7	319	665	471	142	39	11	...	1	...	...	1

Table 7 shows the acknowledged association with other lepers of those entering segregation. It is probable that some have been placed in the "No association" column because the patient has been ignorant of any association which may have occurred. Others have probably denied, or neglected to state, any association in order that relatives or friends might not be apprehended. Though the information is not as complete, nor as reliable as might be desired, it does show that in a rather large per cent of the cases the disease has been present in relatives or intimate associates. The totals in Table 7 do not necessarily represent the number of relatives suffering from leprosy, as some have two or more brothers or sisters who are lepers. The total in Table 7 shows that 110 lepers acknowledge that a brother or sister has suffered from leprosy. In some instances several brothers or sisters have been lepers.

A tabulation has been made of the total number of relatives afflicted which shows the following number, representing plural cases in the families: Brothers and sisters, 70; sons or daughters, 3; uncles or aunts, 31; nephews or nieces, 1. By adding these figures to the totals in Table 7 the total number of relatives afflicted may be obtained.

In that portion of Table 7 giving the number of cases in a family, a "family" has arbitrarily been limited to include the classes of father, mother, brother or sister, son or daughter, husband or wife. This may not include all cases actually domiciled under one roof, and, on the other hand, may include some who are not so domiciled. In six patients, admitted to segregation in the period under consideration, both parents were lepers. This statement should not be construed as showing heredity or infection at birth, as all but one of these children lived with the parents, or leprous relatives, for various periods prior to development of the disease. One case, reported by McCoy and Goodhue (Pub. Health Bull. No. 75, Jan., 1916) was born in the Molokai settlement and cared for in the settlement nursery by clean nurses until the disease was diagnosed.

As all lepers that enter segregation receive treatment, the beginning of segregation is practically the beginning of the treatment of their disease. The duration of the disease before treatment is begun is a matter of great importance, from the viewpoint of both the health authorities and the patient himself. That a patient who has shown the disease, or signs of active leprosy for several years, and during this time has lived in close association with his family and mingled with others in the community, has probably passed his disease on to a greater number of healthy persons than one who has shown signs of leprosy for only a few weeks, will be conceded by all who believe that the disease is transmissible from person to person. Though it is quite generally considered that the contagion of leprosy is comparatively slight, nevertheless the chronicity of the disease causes the period of contagion to be prolonged over a much longer time than is applicable to most of the infectious diseases. Upon the early diagnosis and prompt segregation of the cases of leprosy depends the efficiency of segregation. In the past passive resistance to the law of segregation—that is, the practice of remaining outside of segregation as long as possible—

has done much to reduce the power of the law of segregation in the prevention of the disease.

Leprosy is usually so insidious in its onset, and brings to the patient so little illness or inconvenience in its early stages, that many may have had slight evidence of the disease for some time before they are aware of the true nature of their trouble.

Since the introduction of the treatment of leprosy by chaulmoogra oil, and its derivatives, by intramuscular or intravenous injection, it has been the experience of most of those using these remedies that the early cases yield to treatment more rapidly than those of long standing. It is therefore of greater importance to the patient himself than to anyone else that he begin active and vigorous treatment as soon as he sees any evidence of the disease.

The following case is reported illustrating the result of early treatment. On August 1, 1921, a girl, 7 years of age, was brought to Kalihi Hospital by her father, a leper who had formerly been under treatment at the hospital and was discharged on parole in March, 1921. He was convinced that treatment could alleviate and control the disease. He discovered nodules on the child's ear on the morning of August 1 and at 1 p. m. brought the child to the hospital. Bacteriological examination showed the presence of *B. lepræ* in the nodules. The child was placed upon treatment at once and six weeks later the nodules had disappeared; at this time bacteriological examination was negative and has remained so. The child is still (August, 1922) under treatment, but gives every promise of being freed of her affliction.

When it becomes generally known among the classes in Hawaii that furnish the greatest number of lepers that early treatment gives a better outlook for recovery, and as a consequence the patients seek the treatment, instead of being driven to it by an officer of the law or by the advance of the disease, it may be predicted that a reduction in the incidence of leprosy greater than ever seen in these islands will become evident.

TABLE 8.—*Duration of disease before entering segregation.*

Year.	Less than 6 months.	6 to 12 months.	1 to 2 years.	2 to 3 years.	3 to 4 years.	4 to 5 years.	5 to 6 years.	6 to 7 years.	7 to 8 years.	8 to 9 years.	9 to 10 years.	10 years and over.	A lifetime.	No information.	Total.
1914	5	11	7	9	5	2	1	.....	1	1	1	3	4	5	55
1915	8	14	13	1	11	3	3	1	.....	.....	.....	4	.....	17	75
1916	16	15	12	4	1	2	1	2	.....	.....	.....	5	3	10	71
1917	11	4	17	12	2	4	1	3	.....	1	.....	2	1	18	76
1918	17	10	14	10	11	4	4	4	1	1	.....	8	.....	8	92
1919	10	13	14	15	8	3	4	2	3	1	2	6	.....	17	98
1920	15	13	21	8	6	4	4	5	1	1	1	3	3	13	98
1921	22	9	20	11	8	5	5	3	2	1	.....	6	.....	8	100
Total	104	89	118	70	52	27	23	20	8	6	4	37	11	96	665

Table 11 is modeled after a similar table in McCoy's paper and gives a fair indication of the relative frequency of the first signs or symptoms noted. Without doubt there is a large source of error in this table, as the data are taken from the statements of the patients or relatives at the time of official examination. Furthermore, the tabulation is made from the case records and it is frequently difficult to determine accurately in which class the entry should be made. For instance, a record shows the case is the mixed type of leprosy, the first signs being recorded as "swelling of the face." Unless the compiler has seen the patient (and in most cases he has not) it is extremely difficult to determine whether this should be classed under "swelling of different parts" or under "nodules or thickening."

It is probable that many lepers do not recognize the very earliest symptoms or signs, and consequently give, as their first manifestations, some change that really belongs to a later stage of the disease.

TABLE 12.—*Type of leprosy segregated.*

Year.	Anæsthetic.	Nodular.	Mixed.	Not given.	Total.
1914	5	37	9	4	55
1915	20	44	10	1	75
1916	10	48	7	6	71
1917	9	58	2	7	79
1918	19	57	15	1	92
1919	25	52	21	0	98
1920	19	43	34	2	98
1921	36	43	21	0	100
Total	143	382	119	21	665

Table 12 shows the type of the disease as given in the case records for the different years. It is seen that the majority have been classed as nodular, though in the latter years there is an increase in the number of anæsthetic and mixed cases. It is believed that many cases, which should have been classed as mixed, have been classed as nodular, largely because a nodular or infiltrated area is snipped, and *B. leprae* found therein, and the examination terminated there. This belief is further supported by reading the case histories, which almost invariably describe in detail lesions on the face and upper extremities, and neglect, or describe very briefly, the lower extremities. It has been my experience that anæsthetic patches will be found more often on the legs and feet than in other portions of the body. There is also a tendency to class as nodular all cases in which the bacillus is found in the tissues, though the finding of the bacillus does not necessarily exclude the nerve type.

On the other hand, there is a tendency to class as anæsthetic all held as lepers in whom the bacillus can not be demonstrated. As a matter of fact, a large number are mixed cases, only a few early cases remaining purely nodular in type, while some early and some long standing cases are purely nerve type. One exceptional case now in segregation gives a history of having had the disease 14 years and seems to be a purely nodular case.

The expense to the Territory resulting from the segregation, care, and treatment of lepers and their children continues extremely heavy. All lepers in the Molokai settlement that desire treatment by the ethyl esters of chaulmoogra oil receive it. All lepers in segregation, both at Molokai settlement and Kalihi Hospital, are subsisted, housed, given medical attention, some means of entertainment, and an allowance of funds to purchase clothing or other necessities. The children born of leprous parents in segregation are cared for from birth by non leprous nurses in two homes, one for girls and one for boys.

The following table shows the amount spent in each fiscal year from 1913 to 1921:

TABLE 13.—*Expense of maintenance and treatment of lepers.*

Year.	Amount spent.	Number of lepers.	Per capita cost.	Year	Amount spent.	Number of lepers.	Per capita cost.
1913	$215,664.29	797	$270.60	1918	$227,184.90	728	$312.07
1914	216,578.24	780	277.66	1919	250,004.50	762	328.09
1915	184,192.93	756	243.64	1920	289,751.58	763	379.77
1916	184,353.12	748	246.46	1921	249,687.29	777	321.35
1917	179,360.34	727	248.11				

The legislature that convened in 1921 appropriated for the care and treatment of lepers and their children the sum of $576,680.15 for the two years beginning July 1, 1921.

In this table the number of lepers each year is the total number cared for during the year, considered as present 365 days in the year. The average daily census, of course, would be lower and this would raise the per capita cost. However, these figures are sufficient to show that the leper in Hawaii is well cared for, probably better cared for than this unfortunate class in most parts of the world. All the expense indicated in this table is borne by the Territory. In addition to this the United States Public Health Service furnishes medical attendance at Kalihi Hospital and a part of the medical supplies used.

A STATISTICAL REPORT ON CASES OF LEPROSY WHICH HAVE LEFT SEGREGATION ON PAROLE.

The segregated lepers of Hawaii are confined in two compounds, the Kalihi Hospital, near Honolulu, and the Territorial leper settlement on the island of Molokai. Kalihi Hospital was originally known as the Kalihi receiving station, and persons declared lepers were held there until a sufficient number were assembled to make a transfer to the settlement on Molokai. In recent years it has been required that a leper be held at Kalihi for treatment for a specified time. In some cases improvement has been so great and the evidence of active leprosy has remained absent for such long periods that such cases have been allowed to leave segregation under certain conditions. Likewise a smaller number has been paroled from the settlement on Molokai.

In 1912 the belief that some lepers had improved to such a degree that they were no longer dangerous to the public caused the policy of paroling such patients to be inagurated.

Prior to 1912 a number of cases had been discharged from the Molokai settlement, some of these having been admitted to segregation through errors in diagnosis, and others through what seems to have been deliberate misrepresentation by the patient, in order that he might enjoy the benefits of Territorial support and comparatively easy life.

Briefly, the procedure of paroling is as follows: The attending physician in charge of the case reports that the patient is fit for parole. The president of the board of health then appoints a board of three duly qualified physicians who examine the patient thoroughly and consider the history of the case. If this board of physicians finds that, in the opinion of its members, the patient may be allowed to return home without becoming a menace to others, it recommends that the patient be paroled subject to stated conditions. This recommendation goes to the board of health at its regular meeting, and if approved by this body the parole is granted.

The conditions of the parole require the patient to report to the hospital physician, or some physician designated by the board of health, at intervals which vary according to the individual case. Most of them are required to report weekly, some monthly, and others quarterly. After one year or more, if it seems advisable, the interval may be lengthened by the board of health. The treatment of a majority of paroled cases is continued when they report. The paroled case, therefore, is in a status not unlike that of an outpatient, except that he must be deemed not a menace to the public before he may go on paroled status. It is to be expected that some of these cases will relapse and have to be returned to segregation, though every effort is being made to reduce such occurrences to a reasonable minimum.

Table 1 shows that 249 paroles have been granted to 242 lepers, seven having been returned to the hospital and paroled a second time, after receiving treatment and remaining free of signs or symptoms of active disease for a reasonable time. One of these cases relapsed a second time and returned to the hospital in January, 1922, but this is not included in the table.

TABLE 1.—*Showing number of cases paroled and subsequent history.*

Year.	Number paroled.		Number relapsed.		Died on parole.		Disappeared.		Released from parole.		On parole Jan. 1, 1922.	
	Kalihi.	Molokai.	Kalihi.	Molokai.	Kalihi.	Molokai.	Kalihi.	Molokai.	Kalihi.	Molokai.	Kalihi.	Molokai.
1912	6	0	[1] 1	0	0	0	0	0	0	0	6	0
1913	5	4	1	0	0	0	0	1	2	0	2	4
1914	4	1	0	0	1	0	0	1	0	0	3	1
1915	7	14	[1] 2	3	2	0	0	5	0	0	4	11
1916	8	0	[1] 3	0	1	0	0	0	2	0	3	0
1917	5	12	0	[1] 3	0	0	0	1	1	0	4	10
1918	10	2	[1] 1	0	0	0	1	0	2	1	8	1
1919	44	12	4	1	4	2	1	2	2	0	34	9
1920	30	15	2	4	1	0	1	0	0	0	27	11
1921	70	0	6	0	0	0	0	0	0	0	64	0
Total	189	60	20	11	9	2	3	10	9	1	156	47
Grand total	249		31		11		13		10		202	

[1] Seven patients (4 Kalihi, 3 Molokai) relapsed and subsequently received a second parole, thereby making total number of persons paroled 242 and total on parole Jan. 1, 1922, 195. The 3 paroled from Molokai received their second parole from Kalihi. The small figures preceding an entry indicate the number in that entry who have received a second parole.

Eleven died while on parole, as far as can be determined, of diseases other than leprosy. Thirteen disappeared; two Orientals returned to the Orient; the others may have left the Territory, or may have died, most of them being old long-standing cases paroled from Molokai. Ten have been released from parole and are no longer under surveillance of the board of health or its agents. To obtain this release it is necessary for the patient to undergo a final examination by a board of three physicians and be recommended for release. At present the patient is kept on the paroled status at least four years, after which the patient may make application for release. Some releases have been made after a shorter time on parole on account of special circumstances connected with the case. One of the released patients is known to have died since being released, and I have been informed by a former officer of this station that he found no evidence of active leprosy in this case at autopsy. One case that was released from parole subsequently relapsed and is now under treatment in segregation.

TABLE 2.—*Nationality of paroled cases.*

Year.	Cases paroled.																		
	Kalihi.											Molokai.							
	Hawaiians.	Part Hawaiians.	Portuguese.	Japanese.	Chinese.	Korean.	Filipino.	American.	European other than Portuguese.	Porto Rican.	Total Kalihi.	Hawaiians.	Part Hawaiians.	Portuguese.	Korean.	Filipino.	European other than Portuguese.	Total Molokai.	Grand total.
1912	3	1	....	....	1	....	....	1	......	....	6	....	....	....	....	....	......	....	6
1913	4	1	....	....	....	....	....	....	......	....	5	4	....	....	....	....	......	4	9
1914	4	....	....	....	....	....	....	....	......	....	4	1	....	....	....	....	......	1	5
1915	6	1	....	....	....	....	....	....	......	....	7	14	....	....	....	....	......	14	21
1916	2	4	....	1	....	....	....	....	1	....	8	0	....	....	....	....	......	0	8
1917	....	2	....	....	1	....	....	1	1	....	5	9	1	2	....	....	......	12	17
1918	3	....	[1] 2	1	....	1	....	1	2	....	10	....	1	1	....	....	......	2	12
1919	[1] 26	9	3	2	4	....	....		......	....	44	4	3	2	....	2	1	12	56
1920	[2] 14	8	5	....	....	1	2	....	......	....	30	7	1	5	1	....	1	15	45
1921	41	[1] 13	2	6	1	[1] 2	2	[1] 1	......	2	70	....	....	....	....	....	......	0	70
Total	103	39	12	10	7	4	4	4	4	2	189	39	6	10	1	2	2	60	249

[1] Indicates cases paroled second time.

TABLE 3.—*Frequency of parole and recurrence, by nationalities (1912 to 1921).*

Nationality.	Number segregated.	Number paroles.	Per cent paroled.	Number of relapses.	Per cent of relapses.
Hawaiian	480	142	29.58	15	10.57
Part Hawaiian	168	45	26.79	7	15.55
Portuguese	55	22	40.00	2	4.55
Japanese	49	10	20.41	0	0.00
Chinese	22	7	31.82	1	14.30
Korean	17	5	29.41	2	40.00
Filipino	32	6	18.75	3	50.00
American	6	4	66.67	1	25.00
European other than Portuguese	12	6	50.00	0	0.00
Porto Rican	9	2	22.22	0	0.00
Other Pacific islanders	2	0	0.00	0	0.00
Total	852	249	29.23	31	12.90

TABLE 4.—*Percentage of total admissions, paroles, and relapses contributed by each nationality.*

Nationality.	Admissions.	Paroles.	Relapses.
Hawaiian	56.34	57.44	48.39
Part Hawaiian	19.72	18.18	22.58
Portuguese	6.45	8.68	6.45
Japanese	5.75	4.13	0.00
Chinese	2.58	2.90	3.42
Korean	2.00	1.65	6.45
Filipino	3.76	2.48	9.68
American	0.70	1.24	3.22
European	1.40	2.48	0.00
Porto Rican	1.06	0.83	0.00
Other Pacific islanders	0.23	0.00	0.00
Total	99.99	100.01	100.19

Table 2 shows the nationality of the paroled cases. Comparing the paroled cases with the number of lepers of each nationality entering segregation during the same period, we find that the paroles have been distributed quite proportionately among the different nationalities (Tables 3 and 4). The Chinese, Portuguese, American, and Europeans have a slightly higher percentage of paroles than the other nationalities. However, the relatively small number of individuals in each group makes the percentages of little significance.

Approximately 30 per cent of those entering segregation have been paroled. In the past three years the frequency of parole has been considerably greater. The number of recurrences would indicate that some that were paroled should have been held under observation for a longer period. It will be noted that no Japanese have yet relapsed. This may be due to the return to Japan of any Japanese paroled patient as soon as he observed evidence of relapse.

TABLE 5.—*Sex and age (at entrance to segregation) of paroled lepers.*

Age group.	1 to 5 years.		6 to 10 years.		11 to 15 years.		16 to 20 years.		21 to 25 years.		26 to 30 years.		31 to 35 years.		36 to 40 years.		41 to 45 years.	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
1912	....	....	....	....	3	....	1	....	....	....	....	1	....	....	....	....	....	....
1913	....	....	1	....	....	....	2	....	1	2	3	....	....	....	....	....	....	....
1914	....	....	1	....	....	....	1	....	....	....	....	....	1	1	....	....	1	....
1915	....	....	....	....	3	1	1	3	2	2	....	....	1	1	1	....	1	....
1916	....	....	....	....	1	1	....	1	1	....	2	....	....	....	....	....	1	....
1917	....	....	1	....	3	2	....	....	1	1	1	....	1	....	....	....	....	....
1918	....	....	....	....	2	....	1	1	....	....	1	....	....	....	....	....	2	....
1919	1	....	2	2	2	3	3	^{1}7	7	1	2	7	....	2	5	1	3	....
1920	....	....	2	6	3	4	2	7	5	2	1	3	....	1	2	1	1	2
1921	....	1	2	2	^{1}8	9	^{1}11	7	2	3	4	6	^{2}7	....	4	1	....	....
Total	1	1	9	10	25	20	22	26	19	11	14	17	10	5	12	3	9	2

Age group.	46 to 50 years.		51 to 55 years.		56 to 60 years.		61 to 65 years.		71 to 75 years.		No information.		Total.		Grand total.
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1912	....	....	1	....	....	....	....	....	....	....	....	....	5	1	6
1913	....	....	....	....	....	....	....	....	....	....	....	....	7	2	9
1914	....	....	....	....	....	....	....	....	....	....	....	....	4	1	5
1915	1	....	1	1	2	....	....	....	....	....	....	....	13	8	21
1916	1	....	....	....	....	....	....	....	....	....	....	....	6	2	8
1917	1	1	....	....	1	....	....	1	....	....	1	2	10	7	17
1918	....	1	1	2	^{1}1	....	....	....	....	....	....	....	8	4	12
1919	1	1	....	....	1	....	2	....	1	....	....	2	30	26	56
1920	1	....	....	....	....	....	....	....	....	....	2	....	19	26	45
1921	^{1}2	....	1	....	....	....	....	....	....	....	....	....	41	29	70
Total	7	3	4	3	5	....	2	1	1	....	3	4	142	107	249

Small figure appearing before an entry indicates the number of cases in that entry who have received a second parole.

Table 5 shows the sex and age (at entrance into segregation) of those who have been paroled. The paroles have been relatively more frequent in the female sex (136 male, 106 female) while the incidence of the disease by sex for the same period was 523 males and 329 females. Excluding the second paroles granted to a few patients who have returned to segregation and progressed to a point warranting a second parole, a comparison of the paroles and admissions by age groups is made in Table 6:

TABLE 6.—*Percentage of cases segregated and paroled, 1912 to 1921, by age groups.*

Age group.	Number segregated.	Per cent of total segregated.	Number paroled.	Per cent of total paroled.	Per cent paroled in group.
1 to 5 years	3	0.35	2	.82	66.67
6 to 10 years	46	5.39	19	7.85	41.09
11 to 15 years	146	17.14	44	18.18	30.14
16 to 20 years	155	18.19	46	19.01	29.68
21 to 25 years	138	16.20	30	12.40	21.74
26 to 30 years	96	11.27	31	12.81	32.30
31 to 35 years	63	7.39	13	5.37	20.63
36 to 40 years	55	6.57	15	6.20	27.27
41 to 45 years	45	5.28	11	4.55	24.44
46 to 50 years	36	4.20	9	3.72	25.00
51 to 55 years	21	2.46	6	2.48	28.57
56 to 60 years	23	2.69	4	1.63	17.19
61 to 65 years	11	1.29	3	1.24	27.27
66 to 70 years	7	.82			
71 to 75 years	2	.23	2	.83	100.00
76 to 80 years	2	.23			
81 to 85 years	1	.12			
Not stated	2	.23	7	2.90	285.70
Total	852	100.05	242	99.99	28.42

Table 6 shows that the percentage of parole has been highest in the youngest age group and gradually lessens until the 26 to 30 years group is reached. This group shows a sudden rise and subsequent groups show a slight rise, probably due to the smaller number under consideration. In general, the comparison would seem to warrant the deduction that the younger lepers have a slightly more favorable outlook than the older ones. The discrepancy in the "not stated" group is due to a number in this group paroled from Molokai who were of long residence there, and their records are defective. It may be stated here that 34 of the cases paroled were segregated prior to January 1, 1912, and 208 since that date.

TABLE 7.—*Civil state of paroled cases.*

Year.	Married.	Single.	Widow or Widower.	Divorced.	No information.	Total.
1912	2	4				6
1913	3	6				9
1914	3	2				5
1915	15	6				21
1916	3	4	1			8
1917	6	8			3	17
1918	7	4				11
1919	26	27	1		1	55
1920	17	25	1		2	45
1921	13	50	1	1		65
Total	95	136	4	1	6	242

Table 7 shows the civil state at time of segregation of those who have been paroled. Compared with the figures showing the civil status of those segregated during this period, it is seen that civil status has no appreciable influence on the frequency of parole.

Table 8.—*Occupation of paroled cases at time of segregation.*

Occupation.	1912	1913	1914	1915	1016	1917	1918	1919	1920	1921	Total
Bricklayer										1	1
Carpenter		1			1		1	1			4
Chauffeur and teamster					1			4	2	2	9
Clerks and storekeeper								2		1	3
Electrician			1	1		1		2			5
Farmer		1		1		1	1	1		3	8
Fisherman		1		1	1						3
Foreman						1		1	1		3
Gardener								1			1
House servant		1		1						1	3
Housewife	1	2	1	3		2	3	10	11	6	39
Inmate of Industrial School								1		3	4
Janitor and sexton			1							1	2
Jockey										1	1
Laborer			1	2		2	2	9	5	8	29
Machinist						1			1	1	3
Moving-picture operator								1			1
Prison guard					1						1
Railroad employee					1		1	2	1		5
Seaman										1	1
Soldier									1	1	2
Stevedore										1	1
Student	1			2	1	4	2	4	6	11	31
Teacher							1				1
Telephone operator								1			1
None stated	4	3	1	10	2	5		15	17	23	80
Total	6	9	5	21	8	17	11	55	45	65	242

Table 8 shows the occupation of the paroled cases. In most of these occupations the total number is insufficient to warrant any deductions by comparing them with the occupation of all admitted during the same period. It is noted, however, that laborers constituted 24 per cent of the admissions from 1914 to 1921, while they furnished but approximately 12 per cent of the paroled cases. Similar figures for housewives are 14.75 and 16; for students, 14 and 12.8; no occupation, 24 and 33.

Table 9.—*Duration of disease in paroled cases before entrance into segregation.*

Year paroled.	Less than 6 months.	½ to 1 year.	1 to 2 years.	2 to 3 years	3 to 4 years.	4 to 5 years.	5 to 6 years.	6 to 7 years.	7 to 8 years.	8 to 9 years.	9 to 10 years.	10 years and over.	A life time.	No information.	Total.
1912	2		2					1			1				6
1913	1	1			1					1		3	1	1	9
1914	1	2		2											5
1915		3	4		2	2	1		2					7	21
1916	2	1	2		2									1	8
1917	5	1	1	1	1					1		2		5	17
1918	3	2		2	1	1								2	11
1919	9	11	5	5	2	3	1	2	1	1	1	3	2	9	55
1920	11	4	6	5	3	1		1				2	3	9	45
1921	10	12	14	6	6	1	2		1		1	1	2	9	65
Total	44	37	34	21	18	8	4	4	4	3	3	11	8	43	242

Table 9 shows the duration of the disease prior to entrance t segregation of the paroled cases.

TABLE 10.—*Comparing number admitted, paroled, and relapsed, according to duration o disease before segregation (1912 to 1921).*

Duration of disease.	Number admitted.	Per cent of total admitted.	Number paroled.	Per cent of total paroled.	Per cent of group paroled.	Number relapsed.	Per cent of re-currence in those paroled.
Less than 1 year	246	28.87	81	33.47	32.93	7	8.6
1 to 2 years	133	15.61	34	14.05	25.56	5	14.7
2 to 3 years	92	10.80	21	8.68	22.82	2	9.5
3 to 4 years	74	8.68	18	7.85	24.33	3	16.6
4 to 5 years	37	4.34	8	3.30	21.63	2	25.0
5 to 6 years	36	4.20	4	1.69	11.11	2	50.0
6 to 7 years	29	3.40	4	1.69	13.79	0	.0
7 to 8 years	12	1.41	4	1.69	33.33	2	50.0
8 to 9 years	11	1.29	3	1.24	27.27	1	33.3
9 to 10 years	4	.47	3	1.24	75.00	0	.0
10 years and over	58	6.81	11	4.54	19.00	2	18.1
A lifetime	12	1.41	8	3.30	66.67	1	12.5
No information	108	12.68	43	17.76	39.81	4	9.5
Total	852	99.97	242	100.50	28.40	31	12.8

Table 10 shows that the frequency of parole is greater in those groups which have had the disease for shorter periods. With the exception of the third year group the frequency of parole decreases gradually with each year's duration of the disease until the seventh year group is reached, when it rises sharply. This apparent rise is probably due to the small number of persons in this group, though it should also be mentioned that some cases of long standing may have gone on to natural arrest of the disease and then received a parole. Furthermore, some of the cases of several years' duration at entrance to segregation may be naturally arrested cases which were declared lepers on account of contracted fingers, or other result of the disease, and later, when found to be inactive, have been paroled. This applies to some of the cases whose duration has been "a lifetime." The number giving no information as to duration of the disease should be made up of cases belonging to all groups, as some of these give no history on account of being too young to understand what is wanted, inability to understand English, or other valid reason. As to recurrences, it appears that those coming under treatment early have a lower percentage of recurrences than do those of longer duration, notwithstanding that the greatest number of recurrences occurs in the group that has had the disease less than one year. On a percentage basis, those who had the disease less than one year before entering segregation show a lower rate of recurrence than any other group, except two groups whose total paroled has been very low, and in which no recurrence has yet occurred.

Here again is evidence that the early recognition, and treatment of leprosy is the point on which most emphasis should be placed.

Putting this in another form, we find of those having the disease less than 1 year, 1 out of 3 was paroled; of those having the disease 1 to 2 years, 1 out of 4 was paroled; of those having the disease 3 to 4 years, 2 out of 9 were paroled; of those having the disease 4 to 5 years, 1 out of 5 was paroled; of those having the disease 5 to 6 years, 1 out of 10 was paroled.

It therefore seems apparent that, in the present state of our knowledge of leprosy, we shall achieve best results by bending our energies toward bringing cases under treatment as early as possible. From the standpoint of the lepers, nothing is to be gained by waiting for a positive diagnosis; the delay may result in losing everything.

There are numerous cases of leprosy now in segregation in Hawaii who have been officially examined one or more times before they were held as lepers. It may seem hard on a person to inform him that he has, or probably has, leprosy, but if his signs and symptoms warrant the suspicion of the disease, we do the patient the greatest possible favor by informing him of the fact.

During the past year a girl, who had been officially examined two years before and declared not a leper, died of leprous fever, one month after admission to segregation. She entered segregation, sick unto death, under a diagnosis of typhoid fever, which was not confirmed by laboratory test or autopsy findings. Had this girl been placed under treatment at her first examination, there is every reason to believe she would have responded favorably to treatment.

The rise in paroles after the 6 to 7 year group may be due to the small numbers in each group; and also it may be due to the "survival of the fittest" of the lepers; that is, it may be attributed to the fact that a few persons successfully combat and arrest the disease by natural means, though most of these carry serious deformities and defects.

TABLE 11.—*Duration of treatment (or segregation) of paroled cases.*

Year paroled.	Less than 6 months.	Duration in months.																		
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1912	...	...	...	...	...	...	...	...	...	...	2	1	...	...	...	...	...	1	1	...
1913	...	...	...	1	...	...	1	1	...	2	...	...	...	...	...	...	...	...	...	...
1914	...	...	...	...	...	...	...	1	...	...	...	...	1	...	...	1	...	...	...	1
1915	4	...	...	...	...	...	...	...	2	...	1	...	...	...	...	...	...	...	...	...
1916	1	...	1	...	...	...	...	1	...	...	...	...	1	1	...	1	...	...	...	1
1917	...	...	...	...	...	1	...	...	...	1	1	1	...	...	...	...	...	1	1	...
1918	2	...	...	1	...	...	...	1	1	...	...	1	...	...	...	1	...	...	1	1
1919	...	2	3	2	1	4	5	6	4	3	4	2	1	1	2	1	1	1	...	...
1920	2	3	2	...	2	1	...	2	2	...	...	...	2	...	1	2	2	4	1	...
1921	...	1	5	2	2	5	3	6	5	9	2	3	3	3	5	2	3	...	...	1
Total	9	6	11	6	5	11	9	18	14	15	10	8	8	5	8	8	6	7	4	4

TABLE II.—*Duration of treatment (or segregation) of paroled cases*—Continued.

Year paroled.	Duration in years.															Total.
	2¼	2½	2¾	3	3¼	3½	3¾	4	5	6	7	8	9	10	Over 10.	
1912					1											6
1913													2		2	9
1914								1								5
1915	1			1	1	1			1				1	3	5	21
1916		1														8
1917		1	1			1	1	1	1						5	17
1918						2										11
1919	1	1			1	1		2	2	1			1		2	55
1920	1	1			2	1	3	1		1	2	1	1		5	45
1921	4				1											65
Total	7	4	1	1	6	6	4	5	4	2	2	1	5	3	19	242

Table 11 shows the duration of segregation of those receiving paroles. The first two years are given in months, the second two years in quarters, and the remainder (up to 10 years) in years. The period of segregation is practically equivalent to the period of treatment, though some of the long-standing cases paroled from Molokai may not have taken our present form of treatment. The longest period of segregation was 31 years (1889 to 1920); the shortest one day, one case being paroled by the board who declared him a leper. Table 11 shows that nearly 70 per cent of those paroled were in segregation 2 years or less, and about 8 per cent over 10 years.

TABLE 12.—*Duration of segregation of relapsed cases.*

Duration (months).	Number of cases.	Duration (years).	Number of cases.	Duration of second period of treatment of those paroled twice (months).	Number of cases.
Less than 6 months	2	2	1	5	1
7 months	1	2¼	3	8	1
11 months	1	2½	2		
12 months	2	3¼	3	10	1
13 months	4	3½	1	13	1
14 months	1	3¾	3	16	1
15 months	1	8	1	17	1
17 months	1				
18 months	1				
19 months	2				
21 months	1				
Total	17		14		7

Table 12 shows the duration of segregation of those cases that relapsed. We naturally would expect to find a large proportion of the relapses in those that were treated for a short period; that is, in those we would consider as insufficiently treated cases. However, of the 168 paroled cases treated less than two years, 17 relapsed, and of 74 cases treated two years and over, 14 relapsed.

TABLE 13.—*Type of disease in paroled cases.*

Year of parole.	Anæsthetic.	Nodular.	Mixed.	Not stated.	Total.
1912	1			5	6
1913	6		2	1	9
1914	2		1	2	5
1915	15	3	2	1	21
1916	2	4	1	1	8
1917	3	9		5	17
1918	2	6		3	11
1919	21	27	3	4	55
1920	10	26	1	8	45
1921	11	33	20	1	65
Total	73	108	30	31	242

The type of the disease in the paroled cases is shown in Table 13. Though the greatest number were classed as nodular cases, when compared with the type of those admitted during the same period, we find that the anæsthetic type furnishes a relatively high proportion of the paroled cases. (Nodular cases admitted, 382; paroled, 108; anæsthetic, admitted, 143; paroled, 73; mixed, admitted, 119; paroled, 30; not stated,[1] 13; admitted, 21; paroled, 31.) It is quite generally admitted that the anæsthetic or nerve type of leprosy is the mildest form so far as life and longevity are concerned. Table 13 also shows that in the earlier years no nodular cases were paroled.

TABLE 14.—*Finding of bacilli at official examination of paroled cases.*

Year.	Positive.	Negative.	Not stated.	Total.
1912	1	5		6
1913	3	5	1	9
1914	2	3		5
1915	7	11	3	21
1916	6	2		8
1917	7	5	5	17
1918	10	1		11
1919	36	17	2	55
1920	31	12	2	45
1921	54	10	1	65
Total	157	71	14	242

Table 14 shows the result of bacteriological examination at the time of official examination, the term "official examination" being applied to the examination made when the person is officially declared a leper and placed in segregation. As it is required that all persons going on parole must show no demonstrable lepra bacilli upon examination, it naturally follows that those who have always been bacteriologically negative have a somewhat greater probability of being paroled. However, a large number of those paroled have been bacteriologically positive cases, and this finding by no means indicates that the case will not yield to treatment.

---

[1] The apparent discrepancy in the "not stated" cases is due to the fact that some of these paroled cases were admitted prior to January 1, 1912, the beginning of the period under consideration in this paper.

Table 15 gives the distribution of the first signs of the disease, and it appears that the lesions in the persons that have been paroled have been distributed approximately in the same proportion as in those admitted to segregation, with the single exception of those giving paralysis (usually local) as the first sign. This class of cases has a much greater proportion of paroles. The paralyses are usually relatively slight, many involving only the eyelids; others involve the muscles of the mouth and face.

TABLE 15.—*First evidence of disease in paroled cases.*

	Skin manifestations.			Nerve manifestations.				No information.	Total.
	Spots, macules, leucoderma, etc.	Redness and itching.	Nodules and thickening.	Swelling of different parts.	Numbness of different parts.	Contraction, ulceration, and atrophy of different parts.	Paralysis.		
1912	2						3	1	6
1913	2		1	2		2	1	1	9
1914	1	1	1		1	1			5
1915	2	2	1	2	1	6	5	2	21
1916	1		1	1	2	2		1	8
1917	4		4	3		1		5	17
1918	2	2	1	3		1		2	11
1919	17	1	4	11	3	8	2	9	55
1920	13	1	9	9		4	1	8	45
1921	17	1	16	11	3	4	5	8	65
Total	61	8	38	42	10	29	17	37	242

Table 16 shows roughly the length of time the relapsed cases were on parole. That there will be some relapses among the paroled cases is to be expected. There have been more than was anticipated, yet it is believed that considerable benefit has resulted from the adoption of the policy of paroling apparently arrested cases.

TABLE 16.—*Showing length of time relapsed cases were on parole.*

Year paroled.	Year of relapse.						Year paroled.	Year of relapse.					
	1916	1917	1918	1919	1920	1921		1916	1917	1918	1919	1920	1921
1912				1			1919						5
1913				1			1920						6
1915	2	1			2		1921						6
1916		1	1		1	1							
1917		2					Total	2	4	1	2	4	18
1918					1								

The first cases paroled were few and selected only after very rigid examination. These were so successful that others were paroled later, and still later, with the advent of improved methods of treatment, the requirements for parole became less rigid and possibly too lenient. It should be remembered, however, that the paroling of lepers, so far as concerns Hawaii, is an almost revolutionary departure from the old method of segregation for the remainder of the victim's life.

The paroled cases have done excellent work in teaching the classes in which most of the leprosy in Hawaii is found that the disease is amenable to treatment, and that the life in segregation is far better than the usually gloomy picture so often painted in books and magazine articles. This has caused a considerable number of lepers to surrender themselves and receive treatment, thereby removing dangerous cases from the community. Certainly some influence is causing the Hawaiians to change their attitude toward segregation, and it is believed that the paroled leper returning to his home, and there telling his friends of the conditions in the institution for lepers and of the effect of treatment, is responsible in large part for this change of opinion.

Methods designed to subject all patients to rigid and repeated examination before parole is recommended have been inaugurated, and it is hoped that the relapses in future paroled cases will be fewer.

SUMMARY.

1. During the 10 years (1912 to 1921 inclusive) 249 paroles were granted to 242 lepers in Hawaii.
2. During this period 31 suffered relapse and were returned to segregation; seven of these later received a second parole.
3. The nationality of the paroled cases indicates that the Caucasian race (Americans and Europeans, particularly Portuguese) have responded best to treatment.
4. Compared with the number of cases admitted during the same period the females have received a greater proportion of paroles than have the males.
5. Generally speaking, the younger age groups have furnished the greater number of paroled cases.
6. The probability of the arrest of the disease decreases in proportion to the duration of the disease before treatment is begun up to about the seventh year of the disease. Those surviving longer have a slightly more favorable outlook, probably due to their excellent resistance which has enabled them successfully to combat the disease.
7. About 70 per cent of the paroled cases were in segregation 2 years or less, 22 per cent 2 to 10 years, and 8 per cent over 10 years.
8. Approximately 10 per cent of paroled cases that were in segregation less than two years relapsed; and approximately 19 per cent of paroled cases that were in segregation two years or longer relapsed.
9. Compared with admissions, a greater proportion of the paroled cases were from those classed as the anæsthetic type of the disease.

10. In the 242 that received parole the leprosy bacillus had been found in 157 and in 14 no bacteriological record was made.

11. Generally speaking, the cases showing signs or symptoms of nerve leprosy have furnished a relatively greater number of paroles than those showing skin manifestations.

RELATED PUBLICATIONS.

Available reprints or bulletins on leprosy issued by the Public Health Service from which copies may be obtained without cost:

PUBLIC HEALTH BULLETINS.

No. 66. XXV. Immunity Studies in Leprosy. By Moses T. Clegg, George W. McCoy, and Harry T. Hollmann. XXVI. The Cultivation of Acid-fast Bacilli from Lepers by the use of Symbiotic Organisms. By George W. McCoy. XXVII. A Statistical Study of Leprosy in Hawaii. By George W. McCoy.

No. 75. XXVIII. Chaulmoogra Oil Treatment of Leprosy. By George W. McCoy and Harry T. Hollmann. XXIX. Carbon Dioxide Snow in the Treatment of Leprosy. By George W. McCoy and Harry T. Hollmann. XXX. *B. Leprae* in the Circulating Blood of Lepers. By Harry T. Hollmann. XXXI. Leprosy in a Nineteen-Months Old Child. By William J. Goodhue and George W. McCoy. XXXII. The Cultivation of a Non-Chromogenic Acid-fast Bacillus from a Case of Nodular Leprosy. By Moses T. Clegg. XXXIII. A Note Concerning the Favorable Influence of Glucose on the Growth of Acid-fasts. By George W. McCoy.

REPRINTS FROM PUBLIC HEALTH REPORTS.

No. 607. The treatment of leprosy with especial reference to some new chaulmoogra oil derivatives. By J. T. McDonald and A. L. Dean. August 20, 1920.

No. 627. An epidemiological study of an endemic focus of leprosy. By M. F. Boyd and W. F. Fox. December 17, 1920.

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A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE OHIO RIVER

I. THE PLANKTON AND RELATED ORGANISMS

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PREFACE.

The biological studies which are here reported were made during the years 1914 and 1915 as a part of a more comprehensive study of the pollution and natural purification of the Ohio River, under the direction of Surg. W. H. Frost. The investigation comprised:

1. A sanitary survey of the watershed with special reference to the sources and extent of pollution with domestic sewage and industrial wastes, the sources and quality of municipal water supplies, and the prevalence of water-borne infectious diseases.
2. A hydrometric study, carried out with the cooperation and guidance of the United States Geological Survey, designed to give accurate information as to the discharge of the Ohio at various points, also the velocities and corresponding times of flow between consecutive points of observation.
3. A detailed study of the conditions of pollution actually existing in the river, as shown by chemical, bacteriological, and biological (plankton) examination of samples collected from fixed sampling stations at frequent intervals throughout the period of the study.

The establishment for this study consisted of an administrative office and central laboratory at Cincinnati, Ohio, with five branch laboratories in operation during the spring and summer of 1914 at selected points from Pittsburgh to the mouth of the river. The collection and examination of chemical and bacteriological samples were begun in January, 1914, but the biological survey was necessarily begun later, on August 1, 1914. From that date until October 15, 1914, biological samples were collected regularly from sampling stations in the vicinity of each of the five laboratories, thus covering the full length of the river. On October 15 observations were discontinued except upon the stretch of river from Cincinnati to Louisville. Within this zone the observations begun in August, 1914, were continued without interruption until August 1, 1915, thus extending over a full seasonal cycle.

Owing to interruption during and since the World War, the general report upon the study as a whole is not yet completed. It seems proper, however, to publish this completed section dealing with plankton studies separately and in advance of the general report, for, although the plankton studies attain their full significance only when taken in connection with other phases of the investigation, they are sufficiently distinct in material and purpose to warrant separate publication.

A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE OHIO RIVER.—I. THE PLANKTON AND RELATED ORGANISMS.

BIOLOGICAL INVESTIGATIONS.

ENVIRONMENT AS A BIOLOGICAL FACTOR.

For every form of life in water there is a kind of food, a degree of temperature, a quality or quantity of air or water, a degree of light, perhaps, which is best suited to the particular requirements of the organism. In response to such favorable environment the organism thrives. Any departure from this optimum environment retards the activity of the organism. Any radical change, such as loss of food supply, or sudden extremes of heat or cold, or exposure to a toxic substance or to the attacks of an enemy, may be utterly destructive. The environment may remain essentially the same for weeks or months, changing only with the seasons, or with some similar gradual adjustment of nature, or it may be subject to continuous changes in location, in depth, in rate of movement, in amount and quality of food available, in temperature, in amount of sunlight, and in presence of enemies or of toxic substances. A large lake represents the first of these, stability of environment, while a flowing stream is the fullest expression of a condition of instability.

The plant and animal life of a flowing stream is exposed to a continuous fluctuation of the various factors constituting the environment. Not only are these factors many and varied, but the relative potency of certain ones will vary from time to time, as the moving water encounters an endless succession of physical conformations of channel, or experiences a varying chemical condition due to the continuous transformation of matter derived from many sources, or finds itself burdened with sewage, deprived of sunlight by clouds or by turbidity, subjected to changes of temperature as the seasons progress, or hampered in movement by a covering of ice which meantime reduces its supply of oxygen. Continuous change is the charm of the moving-picture panorama presented by a flowing stream, but this same source of pleasure to the nature lover becomes the vexing instability which tries the patience of the scientific student. "Nothing," says one writer, "is so constant about the environment of the flowing stream as its inconstancy. Instability is the key word of the fluviatile environment."

If the organism have sufficient powers of locomotion, it may select a place, such as a pool or a riffle, and remain there, indifferent to the continuous movement of the water. If, however, it be very small, with insufficient power of movement to resist the flow of the water, it goes wherever the water goes, and is subject to all the changes of environment encountered by the parcel of water which constitutes its home.

It is thus that minute freely floating plant and animal life of water, collectively termed the "plankton," is subject to all the varieties of environment occasioned by the changing conditions as the water progresses toward the mouth of the river. These changing conditions are physical, chemical, and biological.

PHYSICAL FACTORS.

The physical conditions are those which have to do with geographical positions and physical characteristics of the watershed and stream channel, the turbidity and temperature of the water, and access of light.

Topography, velocity of stream movement, and character of surface soil influence turbidity and determine time of passage. Geographical relation of main and tributary streams and seasonal variation affect the temperature of the environment. Sudden and disastrous change may result to the plankton from seasonal or tributary influence.

The relation of volume of water to amount of bottom area and surface exposure, and the presence of bars, islands, bowlders, dams, shallow riffles, and deep pools affect aeration, access of light, temperature, and, it may be, freedom from a near-septic condition on the bottom.

Temperature affects many plankton organisms profoundly. Usually the advent of cold weather results in large decrease in number. However, there are certains kinds that thrive best during the cooler weather of fall or spring. Comparatively few forms flourish during the degree of cold prevalent in our northern rivers. Kofoid (1903) found that when the temperature of the Illinois River fell to 45° F. there was a decrease of over 90 per cent in the total plankton yield.

CHEMICAL FACTORS.

The chemical condition of water becomes a factor in the biological life owing to the fact that all aquatic organisms, both plant and animal, require more or less oxygen; most aquatic plants require carbon dioxide; and the simpler organisms, both plant and animal, utilize to some extent certain dissolved salts and organic substances. These beginnings of life form the connecting link between the dissolved materials in the water and the larger organisms which in turn prey upon the smaller forms to a great extent.

Dissolved salts and organic matter are always present, although in varying amounts, in a stream. They are derived from natural drainage of the land and from the industrial wastes and sewage of cities. The processes of decay and bacterial activity release soluble nitrogen compounds and carbon dioxide to the water. The metabolism of certain organisms results in waste products which are food for others.

BIOLOGICAL FACTORS.

There are, furthermore, numerous interrelationships existing among the organisms themselves, constituting the biological environment. These biological relationships are concerned almost entirely with the matter of food, and are therefore reducible, in the final analysis, to terms of properly related physical and chemical environment. Organisms whose life processes are holophytic (plantlike) are able to elaborate food from dissolved inorganic materials by the aid of sunlight. The plant body thus nourished, however, becomes a prey to various minute animals, some of which are in turn devoured by larger predaceous forms. Other animals are scavengers, and find most of their food in particles of suspended organic matter and in the disintegrating remains of plants or of other animals. Various "chains of food relations" (Kofoid, 1903) are thus established, some being short and simple, while others are surprisingly long and complex, interlinked with many other food chains. Most of these chains finally end in the larger forms of aquatic life, especially fish, these in turn becoming the prey of numerous waterfowl and certain water animals, such as otter, mink, etc. Man himself is to be included among the animals that find much of their food in the larger aquatic organisms, such as fish, turtles, crabs, lobsters, and bivalves.

SIGNIFICANCE OF BIOLOGICAL FINDINGS AND PURPOSES OF THE PRESENT INVESTIGATION.

If it be true that the biological life of a stream is distinctly and profoundly affected by the numerous factors which form the environment, it follows that the organisms in a stream constitute in a general way a reflection of the prevailing environmental condition of that stream. This is true at least to the extent that the presence of any particular organism in unusual abundance is evidence of the relative potency of certain factors existing in that particular environment especially favorable to such organisms. Chief among such factors is food supply.

The securing of adequate supplies of suitable food constitutes the chief activity of practically all water organisms, particularly those of microscopic size. Comparatively speaking, little time is spent in other activities, such as mating, nest building, caring for offspring, etc., which require so large a proportion of the time and energy of larger animals, especially land forms. Microscopic life in water apparently has little else to do except to eat incessantly or assimilate continually. Reproduction by fission or by eggs usually takes place meantime, with but little cessation of the process of eating. Because of this state of affairs it becomes necessary to study with particular care the food habits of these organisms. Some of these food habits may now be briefly considered.

Plants containing chlorophyll or its equivalent require sunlight, by means of which they elaborate their food from simple substances, chiefly CO_2 and water. Thus, a week or more of clear weather is usually followed by a distinct and often remarkable increase of minute aquatic plants, unless turbidity of the water shuts out the sunlight. It will thus be seen that sunshine and turbidity of water are vitally concerned in the food supply of submerged plants.

Various organisms, such as certain rotifers, are, in part at least, herbivorous (Kofoid, 1904, p. 145), finding much of their food in these minute plants, which in turn are dependent largely on sunshine and clear water. Other organisms, notably certain crustacea, are regarded as scavengers because they consume as food the partly decayed fragments of various animal and plant forms. (Herrick, 1884, p. 124; Rafter and Baker, 1900, p. 76.) Most of the ciliates and certain of the flagellates find the greater part of their food in sewage-polluted water. They are most abundant when very large numbers of bacteria are present. Evidently some of these are bacteria eaters (Calkins, 1909, pp. 79, 106; Marsson, in Engineering News, August 31, 1911), while others probably consume suspended organic matter found in such polluted water.

Beyond the mere facts of food supply and preferred habitat, however, there is a still more important aspect of the relations of these organisms to their environment. Knowledge of foods and general activities of these various groups of organisms brings with it certain information concerning the effect of these activities upon the stream, especially in the case of a polluted stream in the course of self-purification. Briefly stated, these two biological aspects, which are distinct though intermingled, are the biological reaction to the environment of the stream and the physical and chemical reaction to the biological activities.

Sunshine and low turbidity favor the growth of diatoms and other algæ whose small size is fairly balanced by their vast numbers, and whose synthetic activity results in appreciable increase of the dissolved oxygen of the water. (Palmer, 1897.) This dissolved oxygen is not only used in the respiration of most water organisms, both plant and animal, but it is quite essential to the process of biochemical self-purification of the stream. Again, crustacea and rotifers, which find much of their food in the general detritus and suspended matter resulting from the decay of plants or other organic matter, are voracious feeders, and when present in large numbers dispose of no small amount of material in their promiscuous and continuous foraging. The organic matter thus consumed removes a considerable burden from the polluted water with corresponding improvement in its chemical and physical condition. Finally, if the water be burdened with sewage, the large amount of organic matter thus introduced is attacked by the bacteria and by hosts of larger organisms conveniently termed septic or pollutional organisms (Forbes and Richardson, 1913, pp. 498, 513) and consisting largely of ciliates and certain flagellates. These feed upon the bacteria as well as upon the organic detritus, and assist in the reduction of polluting material.

As sedimentation is often an important factor in the process of self-purification, it may be anticipated that the biological conditions existing in the bottom deposits when such deposits are present constitute an important phase of the biology of the stream.

The smaller organisms in mud, mostly animal forms, consist chiefly of worms, young mollusks, and insect larvæ and pupæ. The presence of these organisms is largely a matter of food supply, it would seem, for they are found burrowing and delving in the bottom deposits, and the fecal excretions of some of them show a large proportion of mud. Furthermore, the mud itself shows the effects of being worked over by some of these organisms, notably the oligochæte worms. Young bivalve mollusks find their chief food supply in minute organisms in the water, rather than in the mud in which they lie partly buried. In many instances the food habits of the organisms concerned are only partially known. This is particularly true of several of the insect larvæ.

The study of bottom sediments furnishes a sort of summary or average of the conditions that have affected the water while the sediments were accumulating. In the study of the Illinois River, Forbes and Richardson (1913) found that the study of the bottom sludges and deposits was highly important and that "the silt and other deposits accumulating on the bottom of a stream are in some respects more significant of its average condition than are the waters of its current." Recent study of the Potomac River (Purdy, 1916) tends to show similar importance of the bottom sediments.

It will thus be seen that the persistent presence and abundance of certain organisms, or the absence of others, or the sudden advent of certain forms in large numbers, all have a reasonably direct significance with regard both to the environmental condition and to the biological processes of purification that are operative therein.

In order that this significance may be better defined, and hence made of more service in the study of the general problem of stream economy, biological investigations of streams, especially in direct conjunction with chemical and bacteriological investigations, are highly desirable. If the activity of high bacterial content produces appreciable differences in chemical content of polluted water, it seems very probable that the diverse activities of an abundant plankton may also produce appreciable differences. That this is the true state of affairs is indicated by results from the comparatively small amount of work already done in this country, and also by the more extensive work done in Europe, especially in Germany. Whipple (1913, p. 142) says:

> An important question, and one which is of particular interest to water analysts, is the relation between the growth of organisms (plankton) and the chemical analysis of the water in which the organisms are found. Unquestionably there must be such a relation, but thus far our knowledge of the food requirements of the plankton is not sufficient to enable us to tell what this relation is.

Much additional work must be done, however, to give this undeveloped phase of water examination the same standing as that now enjoyed by the better-known chemical and bacteriological procedures. As in the case of the other biological sciences, there is required first routine observation and classification of the phenomena exhibited, together with the associated physical and chemical facts with which these phenomena may reasonably be expected to be correlated. The search for and study of such correlations may be profitably undertaken at the same time, and to this end the various aquatic organisms, including both plankton forms and population of bottom sediments, may be classified or arranged with respect to their attitude toward sewage; that is, their liking for it, indifference toward, or avoidance of it. The recording and classification of a considerable amount of observational material is a prerequisite, however, to any comprehensive generalization.

Many biologists have undertaken such a classification, regarding the organisms as "living reagents" (Kolkwitz, 1911) which react in a definite manner toward sewage or similar pollution.

Whipple (1913) showed that, in the Genesee River, the heavily polluted portion just below the Rochester sewer outfalls furnished very high numbers of bacteria and of certain ciliates and other protozoa. Some miles farther downstream, where chemical and bacteriological evidences of pollution were less apparent, these ciliates diminished greatly in numbers, and certain algæ appeared, these organisms to be followed, some miles below, by rotifers as the dominating organism, and finally by crustacea, as the water became progressively better in quality.

In an elaborate five-year study of the Illinois River for the threefold purpose of determining the biological population, studying the life histories and mutual dependencies of these organisms, and, finally, studying and analyzing the factors of environment, Kofoid (1903, 1904) made a notable contribution to our knowledge of plankton activities. Very briefly summarized, his more important findings are as follows:

1. The age of the water is a vital factor in production of plankton, a long time-factor permitting adequate decomposition of the contained organic matter, which in turn provided sufficient food, directly or indirectly for the aquatic population. Conversely, a short time-factor is unfavorable to plankton growth.
2. There is little correlation between seasonal flux in chemical conditions (as shown by analyses) and seasonal course of plankton production. Nitrogenous matters are influenced, especially by rapid growth of diatoms, but changes are not uniform nor proportional.
3. Temperature affects plankton profoundly. It was noted that when temperature was below 45° F. (=7° C.) the plankton content of the river channel was only 9 per cent of that present when temperatures were higher.
4. Diatoms are frequently very abundant and are of great importance and significance in the food supply of higher organisms. Abundance of other minute organisms containing chlorophyll provides food for large numbers of rotifers.
5. Aquatic insects are important by reason of many food relations connecting them with the smaller plankton organisms.
6. The presence of considerable amounts of organic matter, such as sewage, apparently initiates a well-defined series of biological events, beginning with high bacterial content and large numbers of ciliates. Minute chlorophyll-bearing organisms, both algæ and certain of the Mastigophora, then appear, to be followed usually by larger organisms (rotifers, rhizopods, and crustacea), which find most of their food in the more minute animals and plants.
7. Certain ciliates are very abundant during the height of sewage contamination and bacterial development. They are unusually important in the economy of the plankton, as they feed chiefly on bacteria, decaying organic matter, and the smaller algæ and are themselves eaten by rotifers. These ciliates are active agents in the reduction of sewage, in destruction of the bacteria of decay, and in purification of sewage-laden waters, transferring the matter therein to higher forms of animal life.
8. Plankton production is essentially rhythmic or periodic, the waves or "pulses" being from three to five weeks in duration. Amplitude of pulses is affected by local influences and by season.

Rising temperature, hydrographic stability, decaying vegetation, or access to sewage tend to increase plankton, while declining temperatures, dilution of fertilizing material, access of flood waters, and increase of current all tend to decrease plankton. Initial causes for plankton pulses are traceable through complex food relations which extend from the larger animal forms back to the minute algæ and other synthetic organisms. These in turn are dependent on sunlight and on dissolved matter in the water. Another line is traceable from certain ciliates and flagellates back through the bacteria, which owe their chief food to the contamination, usually sewage, which causes the high bacterial growth.

While the stated objects of Kofoid's investigation made no reference to any particular factor of environment, it is significant that, in a research thus disinterested, there should be frequent allusion to the evident effect of sewage contamination as expressed by the presence of large numbers of certain Mastigophora and ciliates.

Kofoid's work was completed before the opening of the Chicago Sanitary Canal, in 1900, poured a large volume of sewage into the Illinois River. It is therefore fortunate that a further investigation of this stream (Biology of the Upper Illinois, Forbes and Richardson, 1913) gives for comparison the biological conditions which prevailed after the addition of Chicago's sewage. A second object of this later study was "a description of the criteria and effects of different degrees of contamination of the natural waters of the Illinois." (Idem p. 498.) A brief summary of results is here appended:

The average amount of plankton after the opening of the canal was 5.07 c. c. per cubic meter of water, as compared with 3 c. c. per cubic meter previous to the opening. This average increase of 69 per cent was traceable to favorable plankton environment resulting when the largely increased volume of water overspread fertile bottom lands, and sewage from Chicago provided further large amounts of organic matter as food for microscopic organisms.

In correlating distinguishable stages of pollution with their respective chemical and biological characteristics, the river was divided into four sections, in the order of diminishing impurity, and designated by the terms "septic," "polluted," "contaminated," and, finally, "clean water." Analogous terms were applied to the characteristic organisms found in the respective waters. The following is a summary of the chief findings in these four zones of pollution:

Section 1.—Sanitary Canal at Lockport and Des Plaines River at Lockport. (This is about 33 miles below the source of the Sanitary Canal, which, after a flow of 38 miles, empties into the Des Plaines River at Joliet, Ill.)

Character.—Septic.

General and chemical conditions.—In canal, water clear. Offal, human excrement, and general refuse stranded or floating, but little decayed. Noticeable sewage odor. Sludge with foul odor. Dissolved oxygen averaged about 31.9 per cent of saturation. In Des Plaines River, water grayish. Decomposition well advanced. Foul privy odor. Conditions less offensive during cooler weather.

Biological content.—In canal, an occasional living fish. Many dead ones, floating or stranded alongshore. (Fish were a common Lake Michigan species.) No animal life in bottom sludges. Scattered algæ along edges of canal harbored the septic rotifer *R. actinurus* and the protozoa *Bodo*, *Vorticella*, *Oikomonas*, and *Anthophysa*, also septic. In Des Plaines River, bottom stones covered with sewage fungus (*Sphærotilus*) and blue-green algæ. *Anthophysa*, *Carchesium*, *Paramæcium*, and other septic protozoa abundant. Various less septic forms present. No fish in September, a few in November, but in dying condition. Many oligochæte and nematode worms in sludge. No mollusks or crustacea.

Section 2.—Des Plaines River at Dresden Heights (16 miles below mouth of the Sanitary Canal) and Illinois River from this point to Marseilles, a distance of 26 miles.

Character.—Polluted.

General and chemical conditions.—In Des Plaines River, water grayish, with privy odor. Dissolved oxygen averaged 13.1 per cent of saturation. In Illinois River, water grayish and clouded with ufts of sewage fungus (*Sphærotilus*). Masses of putrescent material loating on warmest days. Gas bubbles from bottom. Foul odor rom both water and sludge. Dissolved oxygen ranged from 3.1 to 6.4 per cent of saturation. Unpolluted Kankakee (tributary) showed dissolved oxygen content of 108 to 127 per cent of saturation.

Biological content.—In Des Plaines River, large amounts of *Sphærotilus* and *Carchesium*. The blue-green algæ *Oscillatoria* and *Phormidium* were frequent. Other algæ present during cooler weather. No fish; no vertebrates except one frog. Many dead mollusks. Air-reathing beetles common. No sponges, hydroids, leeches, planarians, r crustaceans. In Illinois River, *Sphærotilus*, *Carchesium*, and *Vocella* abundant. *Colpidium* and *Rotifer actinurus* present. Fish bsent except an occasional specimen. Fungi and *Oscillatoria* in sludge; lso immense numbers of worms (*Tubifex*). No mollusks, crayfish, r larvæ of May fly or Dragon fly. Conditions a little better in cooler eather.

Section 3.—Illinois River from Marseilles (42 miles below mouth of anitary Canal) to Starved Rock, a stretch of 16 miles.

Character.—Contaminated.

General and chemical conditions.—Water grayish. Disagreeable dor. No gas bubbles. Dissolved oxygen about 16 per cent of saturation. Advent of Fox River (relatively pure) and passage of main stream over dam help to improve conditions at Starved Rock, where dissolved oxygen averages 43.6 per cent of saturation near north shore (due to Fox River) and 35.9 per cent near south shore.

Biological content.—*Sphærotilus*, *Carchesium*, *Epistylis*, and other septic organisms very few. At Starved Rock the only sewage organism found is small amounts of *Sphærotilus.* Fish in small numbers along edge of river, farther downstream are found in some variety in mid-channel, and at Starved Rock are moderately abundant. Blue-green algæ (pollutional) fairly common near Marseilles, but scarce at Starved Rock, green algæ increasing meantime. Some worms (*Tubifex*) in bottom mud. Insect larvæ, snails, crawfish, leeches, etc., more numerous.

Section 4.—Illinois River from Starved Rock (58 miles below mouth of Sanitary Canal) to Chillicothe, 107 miles below the canal. This section is 49 miles long.

Character.—Relatively pure water.

General and chemical conditions.—Water very slightly grayish, nearly normal; becomes greenish toward Chillicothe, and the slight odor of sewage disappears. Only in winter do bottom sludges show offensive odor. Dissolved oxygen 22 to 28 per cent of saturation in midsummer, reaching maximum of 82 per cent in November.

Biological content.—Septic and pollutional organisms only occasional or absent. Fish numerous enough to justify commercial fishing. Green algæ predominate, the blue-greens being only occasional. Water is made green by large amount of minute chlorophyll-bearing plankton. Large variety of insect larvæ and of mussels, snails, and crustacea. Sponges, leeches, bryozoa, and planarians are fairly common. *Tubifex* is rare in bottom sediments.

This investigation thus indicates that a water burdened with sewage and "sick" according to all available evidence has meantime a characteristic biological content which is totally different from that shown in the lowest section studied, at which time the physical and chemical conditions also indicate that self-purification is far advanced. The recovering water is now 107 miles below the mouth of the Sanitary Canal, and it still has 180 miles to flow before it reaches the Mississippi River.

A considerable amount of work has been done by European investigators, especially in Germany. Kolkwitz (1911), in studying the organisms and conditions resulting from sewage pollution, divides the water into three zones—the sewage zone, with polysaprobic organisms, and transition zone, with mesosaprobic organisms, and the clean water zone, with oligosaprobic organisms. These terms have essentially the same significance as "septic," "polluted," "contaminated," and "clean water," as used by Forbes and Richardson (1913). This will be evident from the following further explanation by Kolkwitz, essentially as translated by Kuichling:

> *Polysaprobic zone.*—Characterized by multitude of Schizomycetes (bacteria), bacteria-eating Flagellata and Ciliata. * * * From a chemical standpoint this zone is also marked by the predominance of reducing and splitting processes due to lack of dissolved oxygen and to the excess of carbonic acid; also to relatively high content of decomposable food matters, which is indicated by the growth of certain organisms that may be regarded as living reagents.
>
> *Mesosaprobic zone.*—The process of decomposition has advanced to an intermediate degree. For convenience this zone will be divided into two parts, called A-mesosaprobic, and B-mesosaprobic, the first extending upstream and adjoining the polysaprobic zone, and the second extending down stream and adjoining the clean-water or oligosaprobic zone. The first part is usually characterized by the appearance of Schizophyceæ and Eumycetes, along with *Anthophysa vegetans*, *Stentor cœruleus*, *Carchesium lachmanni*, etc. Many bacteria are still present. Drainage ditches carrying imperfectly purified water are good examples of A-mesosaprobic zones. The B-mesosaprobic zone is generally distinguished by its contents of Diatomaceæ and certain Chlorophyceæ, along with Rhizopoda, certain Ciliata, Vermes, numerous Rotatoria, etc.
>
> *Oligosaprobic zone.*—Hygienic interest in the disposal of sewage generally terminates at this zone, while it begins herewith in the case of domestic water supplies. The chief characteristic of this zone is the completion of the process of mineralization; all of the more or less turbulent processes of self-purification are absent in the water itself, and the biological development is usually extensive. The appearance of certain representatives of the Peridiniales, all Charales, and certain planktonal Ciliata, Rotatoria, and Crustacea are to be regarded as characteristic.

Marsson (1911), of the royal Prussian testing station, studied the significance of plankton in maintaining purity of natural waters and the effect of sewage on these organisms. He says of the plankton:

> Its vegetable component is the fundamental food supply or condition of existence for all aquatic life. It comes from the products of the decomposition of * * * decaying animals and plants as well as from sewage. The self-purifying power of natural waters is merely the maintenance of the proper equilibrium between retrogressive and progressive metamorphosis. * * *

After designating as "Food producers" those plantlike organisms which assimilate inorganic matter and, aided by sunlight, build up organic compounds by means of chlorophyll, and further classifying as "Food consumers" all remaining organisms (chiefly animals), Marsson notes the great importance of the activity of algæ in stream economy, and remarks, concerning certain flagellates:

> The euglenas and their relatives are therefore found mainly in nauseous pools whose surface they cover with a green scum. They appear on every sewage farm and especially on the surface of sewage held in tanks. They also develop in great numbers in sluggish indentations of the banks of polluted streams, from which they are carried along by the current. When found plentifully in the plankton, they afford proof that the water has been contaminated.

In discussing "Food consumers" Marsson speaks of the consumption of bacteria by larger organisms, chiefly ciliates, and says:

> These relatively large unicellular organisms thus dominate over the other living organisms in their vicinity, according to their size, like a cannibal among fish. Many of the metazoa, including the Rotatoria, are likewise bacteria eaters and obtain their food in the same manner as the ciliates. Besides bacteria, this food material embraces other bacteria eaters, diatoms, small algæ, etc. If many bacteria eaters are found in a water, it can safely be inferred that many bacteria are present, hence also a quantity of putrefying substances. * * *

Referring to the effect on plankton of organic matter such as sewage, he says:

> It may also be said that the greater the quantity of impurities reaching a stream, the stronger will be the development of the plankton and the greater the amount of work it will have to perform by means of its nutrition and growth.

Eyferth (1900) describes many hundreds of aquatic organisms, both plants and animals. and ranging from bacteria to rotifers. He gives particular attention to the conditions of environment as shown by the preferred habitat of the various organisms, and, as far as known facts permit, states the attitude of each organism toward pollution, using the terms polysaprobic, mesosaprobic, and oligosaprobic, as suggested by Kolkwitz. Senft (1905) similarly regards many of the aquatic organisms as "living reagents" on account of their observed behavior toward pollution, and classifies them accordingly, using the terms of Kolkwitz.

Various other workers, both American and European, have commented on the observed behavior of aquatic organisms toward organic matter, and have regarded this microscopic life as a factor in the self-purification of surface waters. It seems probable that in the study of aquatic organisms we have a source of evidence relative to the true mechanism of self-purification of streams which is sufficiently important to command a respectful hearing along with the better-known evidence obtained meantime from bacteriological study and chemical examination. Referring to the advantage of maintaining a normal distribution of plant and animal life in a polluted stream to the end that organic matter in water may be most effectively disposed of, Whipple (1914, p. 82) says:

> The author believes that ultimately the great question of the permissible limit of stream pollution will be solved on this basis.

In view of all these facts it seemed highly desirable that the investigations of the pollution and self-purification of the Ohio River should include certain biological studies. The purpose of these studies may be said to have been twofold. There was first the general purpose of recording and classifying the available data as a contribution to the biology of streams in general. It was hoped that in addition an intensive study of the biology of the Ohio might furnish some information of immediate importance in the interpretation of the physical, chemical, and bacteriological data that it was proposed to assemble. This branch of the investigation was therefore organized with these two purposes in view.

METHODS EMPLOYED.

PLANKTON.

Purpose, scope, and plan of the biological work.—Recognition of the fact, often noted, that a sewage-polluted stream gradually becomes purified by natural means logically implies that the proper study of such a stream must include a careful survey of all known agents of nature which may be concerned in the purification process. With this end in view it was arranged to study the microscopic plants and animals and the related organisms predominating in the various portions of the river in order that additional data might be secured to consider in connection with the chemical and bacteriological data that were being secured meantime by a study of the same portions of the river.

Laboratories were established at six selected points along the river, as follows: (1) At Pittsburgh, where the Ohio River is formed by the confluence of the Allegheny and the Monongahela Rivers; (2) at Wheeling, 97 miles below Pittsburgh; (3) at Portsmouth, 355 miles below; (4) at Cincinnati, 480 miles; (5) at Louisville, 620 miles; and (6) at Paducah, 920 miles, respectively, down stream from Pittsburgh. The Paducah laboratory was within 47 miles of the Mississippi River, into which the Ohio River flows.

At each of these six cities several sampling stations were established in order to obtain representative samples of the water: (1) Above the city and untouched by local pollution; (2) below the city, and presumably showing the effects of any sewage, industrial waste, etc., introduced locally. Thus, at Pittsburgh, the several biological sampling points were located: (1) 12 miles up the Monongahela from the confluence at Pittsburgh, (2) 7 miles up the Allegheny, (3) 3 miles below the confluence at Pittsburgh, (4) 23 miles below the confluence. This last point also had reference to the condition of the Ohio water before the advent of the Beaver River, which entered at about 25 miles below Pittsburgh. Samples of this tributary were taken well up above the mouth to determine the biological status of this stream. Various other Ohio tributaries, regarded as important on account of their probable sanitary status or their effect as a dilution factor, were sampled in like manner.

Plankton samples were taken weekly as a rule. Bottom sediments were sampled less often—twice a month, or in some cases once a month. The time period covered was August 1 to October 15, 1914, in all stations except those near Cincinnati, where some intensive work was continued until August, 1915.

Table No. 1, given herewith, lists the 6 successive laboratories, 26 collecting stations, time periods covered, frequency of collection, and kinds of samples secured in the effort to secure an adequate and impartial biological picture of the Ohio River. These sampling points are designated on the map of the Ohio River District also.

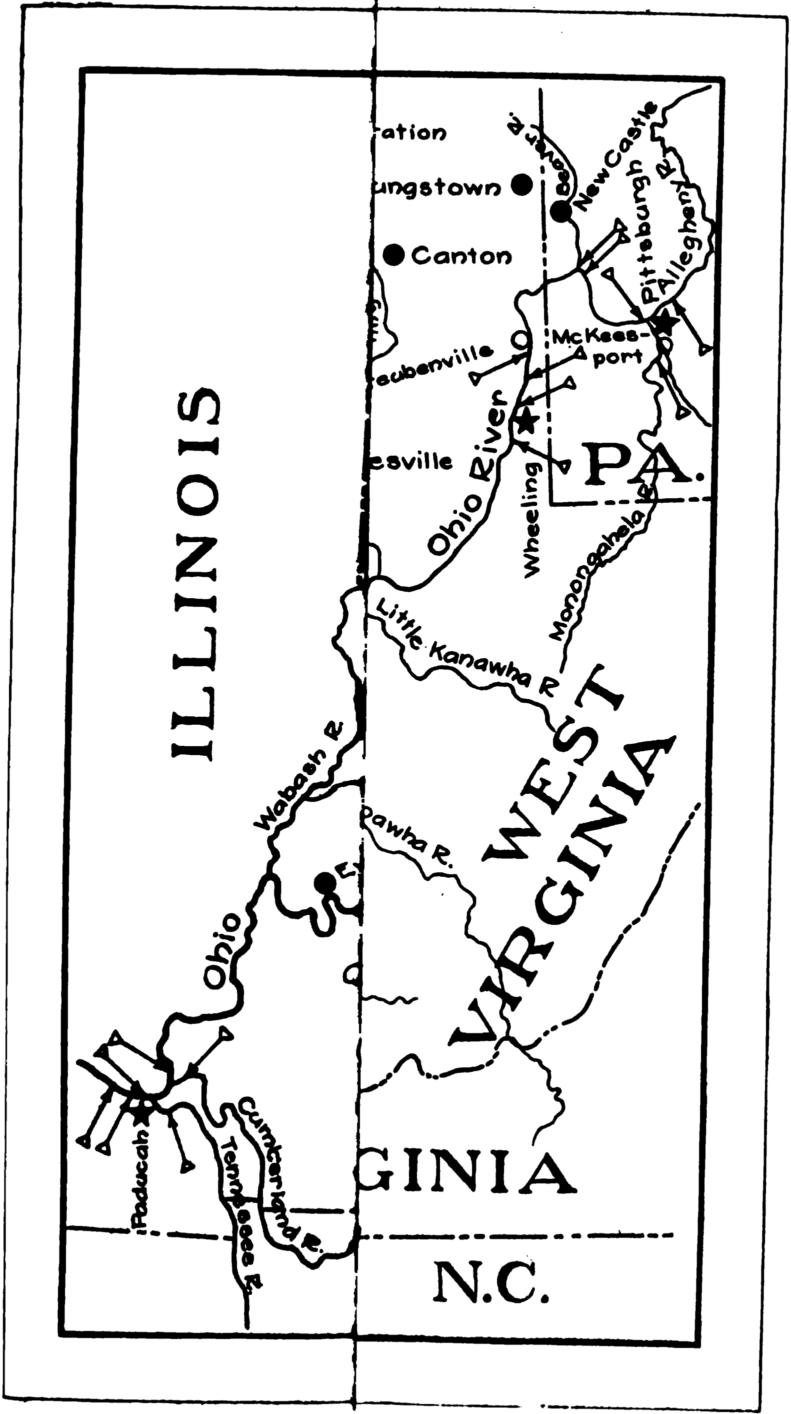
TABLE NO. 1—*Record of biological samples.*

Station.	Sampling point (miles from Pittsburgh).	Time included by samples collected.	Number of samples and frequency of collection.			
			Plankton (weekly).	Mud (semimonthly).	Miscellaneous (occasional).	Total.
Pittsburgh	M-12	Aug. 12 to Oct. 15, 1914.	10	5	1	16
	A-7	do	10	7	1	18
	O-3	do	10	7	1	18
	O-23	do	10			10
	Beaver River	do	10	5	1	16
Total			50	24	4	78
Wheeling	65	Aug. 14 to Oct. 15, 1914.	9			9
	77	do	8			8
	88	do	[1] 4			4
	97 or dam No. 13	do	10			10
Total			31			31
Portsmouth	349	Aug. 18 to Oct. 15, 1914.	7	4	1	12
	Scioto River	do	7	3		10
	358	do	7	4		11
Total			21	11	1	33
Cincinnati	461	July 22, 1914, to Aug. 1, 1915.	46	10		56
	475	do	50	[2] 84		134
	492	Sept. 10, 1914, to Aug. 1, 1915.	49	[3] 49		98
	Little Miami River	Sept. 10, 1914, to May 20, 1915.	33	1		34
	Licking River	July 22, 1914, to June 1, 1915.	36	9	1	46
	Great Miami River	Sept. 10, 1914, to Aug. 1, 1915.	39	2	1	42
Total			253	155	2	410
Louisville	598	Aug. 31, 1914, to Aug. 1, 1915.	49	[3] 87	10	146
	619, N and C	Aug. 31, 1914, to May 1, 1915.	35	34		69
	619-S	do	36	1		37
Total			120	122	10	252
Paducah	904	Sept. 2 to Oct. 12, 1914.	5	3		8
	Cumberland River	do	4	4		8
	920, N and C	do	5	3		8
	920-S	do	4			4
	Tennessee River	do	6	5		11
	926-S	do	4	6		10
	933, N and C	do	5			5
	933-S	do	5			5
Total			38	21		59
Grand total			513	333	17	863

[1] Biweekly.

[2] To November, 1915.

[3] To December, 1915.



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Plankton samples collected at the five branch laboratories were concentrated by use of the Sedgwick-Rafter filter, the resulting catch preserved by adding alcohol, and then shipped to headquarters at Cincinnati for examination. Samples of bottom sediment were preserved by alcohol and shipped to the Cincinnati laboratory for study.

Sampling.—Water samples for Plankton determination were secured by using the Dissolved Oxygen Sampler. This was a cylindrical vessel of about 3 liters capacity and constructed of copper. The air-tight, removable lid was provided with three small tubes, which extended within the vessel, permitting outflow of air and inflow of water. This sampler was lowered nearly to the bottom of the stream, then raised slowly as the water entered, displacing the air. In this manner a "vertical" sample was obtained which was made up of water from bottom to surface of the stream. In most cases, unless the stream was narrow at the sampling point, this procedure was carried out at the three points on a cross section of the channel. The final plankton sample of 2 liters was composited from the water thus obtained. Conditions of weather, stream movement, floating débris, and presence of fish and submerged plants were noted. At the laboratory these data were entered on a field card for convenient reference.

At the laboratory the 2-liter sample was concentrated by filtering through a Sedgwick-Rafter funnel, the catch preserved by the addition of strong alcohol, and labeled with name or number of the sampling station, date, amount of water filtered, and degree of concentration. Later, when the catch was measured by centrifuging, the amount of catch was also recorded on the label.

Examination.—One cubic centimeter of the catch, diluted if necessary, was placed in a Sedgwick-Rafter cell and examined with a binocular microscope magnifying 23 diameters. This was merely a rapid survey of the entire slide in order to note the chief features of the material to be studied, the uniformity of distribution over the slide, and the approximate number and kind of the larger organisms.

Further study was carried on by the aid of a Zeiss microscope with two-thirds objective and No. 4 ocular, giving a magnification of about 60 diameters. The count is made by means of a micrometer eyepiece according to the method given by Whipple (1914), 10 fields uniformly distributed over the slide being examined and the results tabulated.

Identification of organisms.—The organisms comprise eight general divisions, as follows: Diatomaceæ, Algæ, Fungi, Rhizopoda, Mastigophora (or Flagellates), Ciliata, Rotifera, and Crustacea. To these is added a division to include the various minute worms, eggs, spores, or other unclassified organisms that occasionally appear in the plankton. Each of these main divisions consists of several groups, and these are, in turn, divided into other groups or families, with further division into genera and finally species.

Identification has been facilitated by reference to the following: Whipple (1914), Conn (1905) (1908), Miall (1912), Hudson and Gosse (1889), Wolle (1887) (1892) (1894), Leidy (1879), Collins (1909), Tilden (1910), Snow 1903), Eyferth (1909), Senft (1905).

Another helpful means of identifying organisms is by the use of a set of microscope slides on which are mounted for future reference the various organisms as they are encountered in the examination of catches. An organism is removed by a capillary pipette from the counting cell, placed in a few drops of dilute formalin solution in a ringed slide, the cover slip adjusted and sealed down, and the label affixed—the whole process requiring perhaps 20 minutes.

Expression of results.—Results were recorded in terms of "standard units" (a square 20 microns on a side) inasmuch as this method serves to reduce all values to a common basis, and thus shows within certain limitations the approximate relative values of organisms of various sizes and of the amorphous matter and silt as well.

The "standard unit" (Whipple, 1914) is a unit of area and makes no allowance for the thickness of the object. In order to obtain desirable volumetric data, Whipple's recommendation that the standard unit be modified somewhat in practice in case of organisms that vary a great deal in thickness has been adopted. Accordingly, the results of plankton determinations are expressed in terms of standard units which have a constant thickness of about 20 microns, or, in other words, a volume which approximates a cubic standard unit. This is practically the application of a microscopic "board foot," or rather board inch, to the measurement of plankton, and, like board measure, it is essentially volumetric. While such measurement of microscopic objects is not exact, it nevertheless is very much nearer the true values than is obtained if no consideration whatever be given the widely fluctuating dimensions that occur.

In actual practice, the approximate shapes of the various plankton organisms to be measured may be listed as: (1) Globular bodies, (2) cylinders and cones, (3) quadrangular bodies, (4) combinations and irregulars.

Class (1) includes all spheres and near spheres, such as *Volvox, Chlamydomonas, Vorticella* (heads), and many of the ciliates.

Class (2) includes certain of the diatoms, sections of alga filaments, and some flagellates. Such organisms as *Euglena, Cyclops*, portions of certain rotifers and worms, etc., are essentially conical in shape and may be measured accordingly. The desmid *Closterium*, for instance, is practically a double cone.

Class (3) will include such diatoms as *Navicula, Synedra biceps*, etc., and a few algæ such as *Scenedesmus.*

Class (4) includes a variety of organisms, a few of which may be mentioned as typical:

Paramœcium is essentially a cylinder, capped with a half sphere at each end.

Codonella is a sphere attached to a short cylinder.

Cyclops is essentially a cone, with one end rounded into a half sphere.

Synedra is a double wedge.

Rotifers are various combinations of the sphere, the cylinder, and the cone.

Many spherical organisms are very minute. *Pleurococcus* cells may be only 10 or 12 microns in diameter. Eight or more such cells will be required to form 1 cubic standard unit.

In practice, a table similar to that illustrated herewith is a great convenience and timesaver. Such a table, copied from an Engineer's Handbook, may be posted near the workbench and consulted as the count proceeds.

TABLE GIVING AREA OF CIRCLE AND VOLUME OF SPHERE AND OF CUBE FOR A GIVEN DIAMETER.

Diameter.	Area of circle.	Volume of sphere.	Volume of cube.
0.5	0.196	0.065	0.125
1.0	.7854	.5236	1
2.0	3.1416	4.185	8
3.0	7.068	14.15	27
4.0	12.566	33.42	64
5.0	19.635	65.4	125
Etc., up to 30 or 40.			

One or two specific examples will make clear the use of the above table:

(1) Suppose a *Volvox* sphere be found, measuring 22 linear standard units in diameter. A glance at the complete table shows that such an organism has a volume of 5,575 cubic standard units.

(2) A tiny section of alga (cylindrical), one-half standard unit in diameter and 15 standard units long, has a volume of about 3 cubic standard units; that is, area of end (0.196) multiplied by length (15) equals 2.9.

(3) A flagellate (the cone-shaped *Euglena*, for example) whose larger end has a diameter of 2 standard units (linear) with a total length of 6 standard units has a volume of about 6 cubic standard units. (Area of end multiplied by one-third the length.)

(4) A cyclops, whose general shape is that of a cone with rounded base, measures, say, 12 standard units (linear) in diameter at the point where the body begins to round off to form the "head end." From this point to the tip of the tail is, say, 22 standard units in length. The volume is therefore found by multiplying the area of the base by one-third the length, or $113 \times 7\frac{1}{3} = 829$. Add to this the volume of the head end (one-half a sphere whose diameter is 12 linear

standard units) and we have 829 + 452 = 1,281 cubic standard units as the approximate volume. If egg sacs are present they may be measured separately.

By using the ocular micrometer disk devised by Whipple, the approximate volume of all plankton organisms may, with a reasonable amount of labor, be ascertained and recorded on the plankton-counting sheet, thus placing all forms, large and small, on the same volumetric basis and thereby giving an adequate representation of the relative quantitative importance of the various organisms present.

The amorphous matter and silt on the bottom of counting cell is measured in a similar manner. This material, if abundant, usually forms a partial layer of fairly uniform thickness, so the volume may be easily found by multiplying area by thickness on a given field and subtracting the total volume of plankton organisms already counted and measured in this same field. If there be but little of the amorphous matter, the discrete particles and masses in any given field may be measured as were the plankton organisms.

The errors of measurement by the foregoing procedure tend to be so related that if both organisms and amorphous matter or silt be determined by this procedure the relation between the two may be taken as approximately correct. The total volume of the catch is capable of much more accurate determination by means of the centrifuge and actual volumetric measurement, so that by applying to this volumetric measure the relative volume of plankton as determined by the count method a fair estimate of the total volume of the plankton in the catch is obtainable. This is the procedure that has been followed throughout.

Procedure with high turbidity.—Very often the turbidity is so high that it is practically impossible to filter the sample on account of the clogging of the filter by suspended matter and silt. Under such conditions it has been our practice to allow the sample to stand for a few hours, then carefully to siphon off and filter the supernatant water in the usual manner. The heavier suspended matter, which has settled to the bottom, is diluted by the addition of a measured quantity of distilled water. This is now essentially a second catch from the 2-liter sample which has just been filtered. One cubic centimeter, further diluted if necessary, is examined in the usual way in the counting cell and the results tabulated, and later added to the count of the catch obtained by filtering, after first placing both counts on a common basis. Later the settled sediments are measured and the result, reduced to like terms, is added to the quantitative data obtained by centrifuging the other portion of the catch. This material which settled to the bottom of the bottle contained, as a rule, very few organisms.

BOTTOM SEDIMENTS.

Samples.—Samples are secured by the use of a mushroom-shaped scoop dragged on the bottom of the stream by an attached rope. From the liter or two of mud thus obtained the collector takes a representative sample of about 200 c. c., which is placed in a 500 c. c. bottle and taken to the laboratory for examination. In the case of distant stations, the sample is preserved by the addition of an equal volume of strong alcohol, then shipped to the laboratory. The collector makes note of the color, the odor, and the time and place of sampling.

Examination.—The laboratory examination of these samples consists in noting the color, the odor, and the consistency or "streak." Following this, the mud is carefully washed through a fine-mesh sieve. This is accomplished by placing the mud in some such vessel as a "moist chamber"—which has perpendicular sides—running tap water into it and agitating and rotating the vessel until the water is very turbid with mud in suspension. This is then poured through the sieve. More tap water is then added, and the process repeated as often as necessary until all the mud has been passed through the sieve, whose fine meshes retain the larger organisms present (worms, insect larvæ, mollusks, etc.) and the various kinds of disintegrating organic material, chiefly fragments of leaves, plants, seeds, small sticks, molts of water animals, etc. This is essentially a process of filtration and the "catch" in the sieve is transferred to a vessel of clean water for convenient study. Results are tabulated under appropriate headings. No quantitative estimates are attempted aside from using a sample of constant size (200 c. c.). Organisms present are merely counted. Disintegrating organic material is recorded as to predominating kinds and relative abundance.

Table No. 2.—*Summary of examination of bottom deposits.*

Station.	Samples, 200 c. c.					No organisms present: samples rated by physical condition only.			Samples rated by organisms.									Samples classified by the number (expressed in per cent), which show various degrees of pollution.							
	Time included by samples.	Number collected.	Composition.						Pollutional organisms.			Indifferent or doubtful.			Clean-water organisms.			Physical condition: Polluted. Pollutional organisms: Abundant.		Physical condition: Doubtful. Pollutional organisms: Moderate number or few. Doubtful organisms: Abundant.		Physical condition: Doubtful. Doubtful organisms: Moderate number or few.		Physical condition: Clean. Clean-water organisms: Present.	
			Mud.	Sand.	Gravel and pebbles.	Polluted.	Doubtful.	Clean.	Abundant.	Moderate number.	Few.	Abundant.	Moderate number.	Few.	Abundant.	Moderate number.	Few.	Pollution abundant.		Moderate amount of pollution.		Pollution slight or doubtful.		Pollution absent.	
																		(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
M-12	August to Oct. 15, 1914	4	4			2	1		1									75		25					
A-7	do	6	5		1			1	3	1	1							60		40					
O-3	do	7	5	2			2		5									100							
O-23	No mud found																								
Beaver River	August to Oct. 15, 1914	5	5				1		2		1							40		20		40			
Wheeling district	No mud found																								
349	August to Oct. 15, 1914	4	4				1			2	1									100					
Scioto River	do	3	3							2	1									100					
358	do	4	4				1				3									100					
461	July 20 to Nov. 20, 1914	10	9	1			1	3			2		4							40	22	20	55	40	22
Licking River	July 20 to Nov. 5, 1914	9	7	1	1			3	3	2	1							50	43	33	43			17	14
475	July, 1914, to November, 1915	84	61	15	8		1	22	51	4	3	1	1	1				94	84	6	16				
492	September, 1914, to December, 1915.	49	3	44	2			46	1	1	1							50	33	50	67				
598	do	87	60	14	4		1	19	17	14	25	4	2	4		1		10	25	80	62	10	9		4
619	September, 1914, to Apr. 30, 1915.	35	4 Tr.	30	1			30	3			1						67	75	33	25				
904	Sept. to Oct. 15, 1914	6	4	2				3		1	1			1						50		25		25	
Cumberland River	do	4	4								1		2	1						50		50			
920	do	2	2											2								100			
Tennessee River	do	5	5							1	1		1	2						40		60			
933	do	5	5				1					1	1	2						20		80			

Note.—Figures in column (A) refer to samples collected at all stations during August, September, and October, 1914. Figures in column (B) include the additional samples taken in Cincinnati-Louisville interval. Samples consisting of sand or gravel are not included in per cent calculations given.

RESULTS OF BIOLOGICAL INVESTIGATIONS.

In presenting the result of the biological studies of certain portions of the Ohio and its tributaries it is deemed advisable to set down in the same place a summary of those physical, chemical, and biological characteristics of the stream that may be supposed to determine or be influenced by the presence of the microscopic plant and animal life under investigation.

These various characteristics have been studied in detail and are described more fully in the separate report upon hydrometric, chemical, and bacteriological studies of the river. An effort to summarize the essential factors, giving to each its due weight, and thus to arrive at some reasonable conclusions as to the general biological situation at any given station, is a task attended by perplexing problems and real difficulties. Aquatic life responds to changes in its environment. If this environment be made up of many and diverse factors, the resulting biological situation is correspondingly complex. As stated by Kofoid (1904, p. 41), the organisms in a stream constitute "the biological expression of the state of tension among these various factors which for the moment exists," the factors referred to being a most complex series "whose number and relative potency are subject to constant change and readjustment in the unstable environment of the stream."

It will not be attempted, therefore, to analyze the environmental conditions in terms of biological activity, but rather to set down side by side a summary of the river characteristics and of the biological findings at each station in order that the way may be partially prepared for a study of whatever correlations may exist between the two. That such correlations do exist may be anticipated from general biological principles; and certain marked tendencies are plainly apparent in the data that will be presented in the following pages. It is only by the painstaking collecting, recording, and analyzing of a large amount of observational data of this sort that it will be possible to arrive at a state of knowledge of the ecology of microscopic life comparable with the similar knowledge which now exists in the case of the better-known higher plants and animals.

THE OHIO RIVER.

The Ohio River, formed in southwestern Pennsylvania by the confluence of the Allegheny and Monongahela Rivers, flows in a general southwesterly direction and empties into the Mississippi near the present city of Cairo. Its total length of 967 miles forms the dividing line between the States of Ohio, Indiana, and Illinois on the north and Kentucky and West Virginia on the south. The chief tributaries from the north are the Beaver, Muskingum, Scioto, Miami, and Wabash Rivers; tributaries from the south are Kanawha, Licking, Kentucky, Green, Cumberland, and Tennessee Rivers.

The total area of the watershed drained by the Ohio and its tributaries is 203,000 square miles and constitutes the major portions of the States named above (except Illinois) and smaller portions of New York, Tennessee, Alabama, Illinois, Pennsylvania, Virginia, and North Carolina.

This watershed is in general characterized in the eastern part by rugged, hilly country, with comparatively small flood plains and level areas. But in the lower and western portion the general ruggedness gives way to comparatively large stretches of rolling or nearly level areas along the less rapid main stream or its larger tributaries, notably the Wabash.

The geographical position of the main stream is such that tributaries of the upper portion are subject to rather rigorous winter conditions, with the result that spring thaws produce high floods, which erode the banks and scour the channels of tributaries and of the main stream and carry very large amounts of suspended matter and silt downstream. Fluctuations of level and consequent erosion in the upper portions are further induced by the general ruggedness of the watershed and the relatively steep slopes of the channels. On the other hand, such tributaries as the Cumberland and the Tennessee Rivers, coming from the south and joining the Ohio in the less rugged lower portion, are not subject to such extremes of temperature and level.

The channel of the main stream is characterized by numerous islands, bars, wide shallow riffles, and a few deep pools. Hills noted for their beauty adorn either bank. Flood plains are few and comparatively small in size. There are no extensive back-water areas, with the result that there is little opportunity for flood water to be retarded by temporary overflow on such lowlands. These natural checks of turbulent, destructive floods are practically absent in the upper two-thirds of the Ohio channel, and are but few even in the lower portions.

These natural conditions are modified somewhat by the numerous dams that have been constructed along the river. These now number 38, and more are being built. Most of them are of the "beartrap" type, so constructed that they may be laid down, allowing the water to flow over their sills without obstruction; or at low stages they may be raised, forming pools of sufficient depth for river transportation purposes. Ultimately, by the aid of these dams, the river will be navigable from mouth to the source at Pittsburgh, and the series of pools thus formed will profoundly affect the biology of the stream.

The main sources of direct sewage pollution of the Ohio River are the metropolitan districts of Pittsburgh, Cincinnati, and Louisville. Relatively small amounts of polluting matter, chiefly sewage, are contributed by Wheeling, Huntington, Portsmouth, Evansville, and Paducah. Certain tributaries whose well-populated valleys find convenient disposal of their sewage in the local stream tend to increase by a small margin the load already carried by the main stream. This is true of the Beaver River, also of the Scioto. The majority of the tributaries, however, tend to dilute, rather then to concentrate, the sewage content of the Ohio.

The initial pollution at Pittsburgh consists essentially of the untreated sewage from a population of 1,000,000, in round numbers, together with a large amount of industrial wastes, details of which will be given elsewhere in the complete Ohio report. The second heavy pollution occurs at Cincinnati, where the river receives the untreated sewage from more than half a million population. However, in the 480-mile flow from Pittsburgh the stream has largely recovered from the initial pollution and has been augmented by tributaries until the volume of water at Cincinnati is more than four times that at Pittsburgh. Similarly, at Louisville the pollution incident to a population of 300,000 is received by the stream which, after a flow of 120 miles from Cincinnati, has been increased measurably by the advent of the relatively clean Miami and Kentucky Rivers, thus increasing, rather than diminishing, its capacity for the disposal of the organic matter received at Louisville.

THE PITTSBURGH DISTRICT.

In brief, certain of the factors that may affect the biological situation at Pittsburgh are:

Two streams, the Allegheny from the north and the Monongahela from the south, with unequal volumes of dissimilar waters, unite to form the Ohio.

The Allegheny, contributing 60 per cent of the water, is characterized by severe winter conditions, a quick-spilling basin, steep and uniform slope, widely scattered population and points of pollution, and a short time-factor for biological action in the 24-mile slack-water basin formed by three dams just above Pittsburgh. The water is alkaline and usually turbid.

The Monongahela, contributing 40 per cent, has comparatively mild winter conditions. Floods from the quick-spilling basin are checked by the 131-mile slack-water stretch formed by continuous dams, which thus insure a long time-factor for sedimentation and biological reduction of sewage and waste from a large and concentrated population and from industrial establishments lining the river banks. The water is generally acid from mine drainage and but slightly turbid.

A slack-water basin extending nearly 5 miles below Pittsburgh (except during high water) receives these two tributaries, together with large amounts of untreated sewage and industrial wastes discharged directly into this basin along Pittsburgh's total water frontage of 31½ miles.

Finally, abundance of organic material in various stages of decomposition, restored alkaline reaction, and a considerable time element constitute a favorable environment for biological action at this point.

Samples were taken from each of the two rivers at points some distance above the point of confluence and above the portion of the Pittsburgh water front where sewage and wastes are added to the river. The sampling point for the Allegheny River is 7 miles upstream from the confluence of the two streams, and is designated by A–7. The Monongahela sampling point is 12 miles above the confluence and its designation is M–12. At O–3, 3 miles below the confluence, samples were taken to ascertain the content of the mixed waters. Similarly, O–23 designates a sampling point sufficiently far below Pittsburgh to insure thorough mixture, as well as a considerable time interval for biological action and sedimentation, through the agency of five successive pools formed by as many dams. Samples were also taken in the mouth of the Beaver River, which enters the Ohio 25 miles below Pittsburgh.

Water from these five sampling points show the biological condition of the streams on reaching the Pittsburgh district, but before the access of sewage and wastes from the city itself; after the two tributaries combine and have meantime received sewage and industrial wastes in large amount from Pittsburgh; after the complete mixing. sedimentation, and detention caused by the five dams; and at the mouth of the Beaver River.

The average results of weekly examinations made during the months of August, September. and October. 1914. are given in Table No. 6 (p. 53) and the principal features are shown graphically in planktograph No. 1 (p. 58).

Station M–12.—Ten weekly samples taken at M–12 during a period of relatively stable conditions of temperature, river stage, and turbidity showed a relatively constant content of organisms. both as to amount and kind. Organisms averaged 5.3 to 6.4 per cent of catch (monthly averages). Rotifers constituted 89 to 96 per cent of all organisms present. Lack of variety and total absence of green algæ further characterized the plankton.

This sampling point, located near the lower end of the 131-mile slack-water stretch, represents water which has been subject to heavy pollution by sewage, by industrial wastes, and by drainage from coal mines. But it has also enjoyed the great advantage of a long time-factor. Except for one item, this combination of factors would, in all likelihood, insure great productiveness and activity among the plankton organisms, for food is abundant and the impounded water gives ample time and quiet for reproduction. The factor whose effect is not definitely known is the mine drainage and the pickling wastes from steel mills, which tend to make the water acid in reaction. The bacterial content of the water is very low and out of all proportion to the large amounts of pollution entering the river. It is extremely probable that any substance thus toxic to bacteria would to an appreciable extent affect the plankton forms also.

Further data, and laboratory experiment as well, are necessary before it may be said in just what manner this unfavorable environment affects the smaller organisms of the plankton. The effect may be direct, especially to plantlike organisms, resulting in the more or less speedy death of these minute forms when the water in which they have been reared is presently mingled with that in the lower part of the slack-water basin where the reaction is prevailingly acid. Or the effect may be exerted indirectly by the killing off of the bacteria which form a large part of the food supply of many of those plankton organisms which ingest food particles rather than absorb dissolved material as do plants. Regardless of the acidity of the water, these organisms could not be present in numbers when their chief food supply is not to be found. It has been observed repeatedly (Kofoid, 1904, pp. 116, 117, 120) that such forms as those mentioned above disappear from the water when a considerable degree of purification is indicated by the diminishing numbers of bacteria. There is a vital relationship of some kind existing between them.

Plankton is abundant at M–12, however, but it is limited to a very few organisms. Rotifers constitute 89 to 96 per cent of all organisms found, and these rotifers are of two kinds only.

It seems reasonable to assume that these narrow limits as to variety of organisms which comprise the plankton are the result of some unfavorable influence which eliminates all forms except these few varieties.

The question of food supply for some of these organisms is a matter of interest. The most abundant rotifer, *Brachionus*, is herbivorous, or, at any rate, omnivorous, in common with most of the ploiman rotifers (Kofoid, 1904, p. 145), and is thought to find most of its food in phytoplankton, that is, minute chlorophyll-bearing organisms. But these minute organisms were not found at all in the samples. It is possible that the difficulties of recognizing them in the preserved catch might account in part for this result, but such human limitations would not give wholly negative results in every sample examined.

It seems probable that these rotifers would find their chief food supply in the abundant organic matter in suspension in the water incident to heavy sewage pollution and incident, further, to the absence of sufficient bacterial life to dispose of this material.

We thus see at M–12 the unusual spectacle of a plankton which has responded to the very favorable conditions of environment, abundant food, and very long time-factor, but which has meantime been subject to some biological catastrophe which has nearly or quite eliminated the first few links in the chain of organisms whose interdependence arises from their food relations. The resulting plankton is large, but consists of a very small variety of the larger organisms—the biological end-product of the complicated reactions due to the dominant factors of abundant food, long storage, and, probably, acidity of water at this station.

Station A–7.—In the Allegheny at Station A–7 during the same period the temperature ranged from 24° C. to 16° C., turbidity from practically zero to 60, and river levels recorded by the gauge at Freeport, Pa., fluctuated from 0.7 to 2.2. The monthly average plankton content varied from 0.2 to 1 per cent of total catch.

Rhizopods held leading place in September and diatoms in October Noticeable features of plankton were variety of organisms present, unusual scarcity of organisms in August samples, and relatively small plankton yield at all times.

The water is of comparatively recent origin owing to the gradual and considerable slope of 2 feet per mile in the lower 85 miles of this river and owing, further, to the absence of any slack-water basin that is sufficient in size to impound the large discharge of this stream for more than a short period. The river is thus very sensitive to flood conditions, and consequently the short slack-water stretch just above Pittsburgh is subject to quite frequent renewals of the water. This condition is disastrous to plankton life generally (Kofoid, 1903, p. 458) by preventing that adequate decay of sewage which would furnish plankton life with abundant food and, further, by providing a time-factor which is far too short for the breeding of plankton in quantity. The partially decayed organic material, together with such plankton as may be present, are swept on into the Ohio by the frequent floods.

Conditions similar to the foregoing were found in the study of the Illinois River by Kofoid (1903, pp. 349, 458). The plankton production of a certain tributary (Spoon River) averaged only one-fiftieth that of the main stream, and the only available explanation was found in the fact that the water of the tributary was of recent origin and the relatively rapid current caused such frequent renewal of the water that there was insufficient time for the breeding of plankton in this tributary stream. Kofoid concluded: "*The age of* *the water* is, other things being equal, one of the most vital of all the hydrographic factors environing the plankton."

The organisms found in samples at Station A-7 apparently reflect the varied and somewhat unstable conditions of environment.

For some reason not apparent, August samples yielded very few organisms. Turbidity had reached a maximum of 90 the day preceding our first collection, although the gauge at Freeport showed a rise in levels of only 2 feet. It is possible that this influx of turbid water, probably from some tributary, reacted unfavorably on August plankton.

September samples reflected the moderate disturbance of river levels by showing predominance of the rhizopods *Difflugia* and *Arcella*, both of these organisms belonging normally to bottom sediments or to the surface of decaying plants or other organic matter. Their prominence in plankton samples is usually a function of disturbed conditions of stream flow. Holophytic (plantlike) organisms are moderately abundant as a result of comparatively low turbidity, premitting access of sunlight. In turn, the rotifer *Anuræa,* which feeds principally on minute plant life, is present in small numbers. *Anthophysa,* a colorless flagellate, usually abundant in contaminated water, is present also.

Cooler temperatures in October favor the growth of diatoms, which are found moderately abundant. A rise in water levels brought the bottom-loving organisms *Difflugia* and *Arcella* again into the plankton in the last sample, together with a large amount of suspended matter.

Station O-3.—Ten weekly samples taken at O-3 during this period of very moderate fluctuation as to temperature and turbidity show a monthly average plankton content of 7.6 to 8 per cent of the total catch.

Organisms present show moderate variety, rotifers predominating, comprising 91, 66, and 61 per cent of all the plankton forms in the three months, taken in order. Ciliates appear in moderate numbers. Crustacea and diatoms are present in small numbers. Neither diatoms nor algæ appear in August, both are found in September, and algæ again in October.

Hydrographic conditions were so nearly uniform and stable that the plankton catches may be regarded as truly representative of prevailing low-water conditions at this station—the first in the Ohio River proper.

Abundance of plankton in all catches means that suitable food for these organisms is plentiful. This necessity is evidently supplied partly from the two tributary streams that unite to form the Ohio River and partly from the great volume of sewage and industrial waste contributed along the Pittsburgh water front. It is evident that this organic matter thus supplied from these sources will vary greatly in age and in stage of decomposition; that from the Monongahela having been subject to a very long time period, but in water of acid reaction; that from the Allegheny River representing a variety of ages on account of the widely scattered locations of the towns on its watershed; and, finally, the sewage and waste from Pittsburgh representing a comparatively fresh condition.

It would seem that this organic material of different kinds, of different ages, and hence in various degrees of decomposition, would supply all necessary food requirements for a large and varied assortment of plankton organisms.

The slack-water basin formed by the dam a short distance below this sampling point provides comparatively still water along the entire Pittsburgh water front, thus imposing on the mingled waters forming the Ohio River a moderately long time-factor which would tend to encourage biological activity. This, with the presence of abundant food, should produce a heavier growth of plankton than we find at O–3.

Reference to the chemical data reported in another section will show that during August, September, and October, when our samples were taken, the acidity of the Monongahela had been neutralized by the alkaline water of the Allegheny and the acid salts of the Monongahela had been largely eliminated. There are probably many reactions and adjustments taking place of which we have no direct knowledge. We know only these end reactions or the final outcome.

This beginning of the Ohio River at Pittsburgh is evidently the arena in which the dissimilar waters of the two tributaries settle their differences of chemical reaction and physical condition and acquire the final adjustments which appear in samples taken at O–11, this final outcome being hastened, or variously modified, presumably, by the large amount of industrial wastes and sewage introduced at Pittsburgh.

It seems highly probable that the acidity of the Monongahela might at times be a factor at O–3, for occasional acidity was noted in daily samples at O–11, where chemical samples were taken. This probability is strengthened, moreover, by the fact that during one month of this period (August) the discharge of the Monongahela was 2,070 second-feet and that of the Allegheny was 1,660 second-feet, a reversal of the usual order of relative discharge of these streams.

Any such occasional acidity at O–3 would be likely to exert unfavorable influence on the development of plankton life, as is the case at M–12. Moreover, the various changes in the concentration of dissolved materials (including acid salts) that must be a part of the process of readjustment in this physiochemical arena would undoubtedly show a biological reflection in a decreased plankton production.

The plankton-poor water of the Allegheny will function as a diluent of the more abundant plankton contributed by the Monongahela. Inasmuch as the usual discharge of the Allegheny is considerably in excess of that from the other tributary, it is no surprise that the plankton at O-3 reflects this diminished relative value and, to some extent, shows something of the variety of organisms which characterizes the scanty plankton contributed by the larger stream.

Abundance of organic matter is indicated at O-3 by the prevalence of the same rotifers, *Brachionus* and *Rotifer vulgarus*, which we find predominant at M-12. Distinctly pollutional organisms, *Anthophysa* of the Mastigophora and *Vorticella* and *Epistylis* of the Ciliata, appeared in five samples. *Vorticella* formed 29 per cent of the entire catch in one of these samples and from 1 to 9 per cent in three other samples. *Rotifer actinurus*, a pollutional organism (Forbes and Richardson, 1913, pp. 502, 513), appeared in moderate abundance in 1 sample, while in 7 of 10 samples the contaminate *Rotifer vulgaris* was abundant.

Station O-23.—At Station O-23, 10 weekly samples taken during a period of relative quiet as to water conditions show a moderate assortment of organisms. Rotifers predominate in two months and crustacea in one. Diatoms are abundant in one August sample Green algæ, Mastigophora, and ciliates are present in rather small numbers. A noticeable feature of collections here is the decline of rotifers as the leading plankton and the gradual advent of crustacea.

Diatoms (*Synedra delicatissima*) are abundant in one sample only, that of August 25. Temperature was 24° C. The sudden appearance of this organism, which is usually more abundant in cool weather than in warm, seems to be without explanation except for the fact that the "bear traps" had been lowered a few days before and the pools were drained of some of their surface water. This disturbance and readjustment of levels might be responsible for the appearance at this station of the relatively large number of diatoms whose growth and multiplication had probably taken place in some sheltered bit of water in one of the upstream dams. It is worth noting, also, that an unusual number of *Brachionus* (the same rotifer that is so abundant at O-3 and at M-12) appeared in this same August sample at O-23. The lowering of the "bear traps" was reported August 18, one week before this sample was taken.

The list of organisms, together with relative abundance of certain kinds, indicates some improvement in the water. Two organisms of recognized pollutional affinities, *Euglena viridis* and one of the *Vorticellidæ*, were present in moderate amount in one sample, and a very few of the former organism in a second sample. However, the presence of *Brachionus* in 5 of the 10 samples would indicate sufficient organic matter to furnish food to this rotifer, which is classed by some writers as a contaminate organism. (Eyferth, 1909, p. 534.) On the other hand, the better condition of the water is attested by the fact that the pollutional rotifers *R. actinurus* and *R. vulgaris*, which were fairly abundant at O–3, are entirely absent here; the pollutional protozoa *Anthophysa* and *Epistylis* are likewise absent. Moreover, a rotifer of recognized cleaner water environment, *Anuræa* (Kofoid, 1904, p. 151), is here found in four samples, while it was entirely absent at O–3. The minute algæ which constitute much of the food of this rotifer is present at both O–3 and O–23.

Perhaps the most notable feature of plankton at this station lies in the fact that, while rotifers hold first place quantitatively in August and September, the crustacea (*Cyclops*) assume this rôle in October and maintain it, as far as rotifers are concerned, in plankton collections farther down the river at Wheeling. In food habits *Cyclops* is a scavenger (Herrick, 1884), and its presence means the destruction of much of the organic matter that has thus far escaped or survived the attacks of bacteria, ciliates, and certain rotifers.

This station is in the lower part of pool formed by Dam No. 5, hence, between the last station considered, O–3, and this point intervenes a stretch of 20 miles of water, all of which is impounded by Dams Nos. 1 to 5, inclusive. According to data given in the hydrometric section of the full report,[1] the time of flow between these two stations was 5.59 days in August, 6.20 in September, and 12.49 days in October 1–15. It will thus be seen that the time interval concerned is out of all proportion to the distance traversed. That this very slow movement of water provides sufficient time interval for considerable biological activity would seem to be demonstrated by the fact that the plankton at O–23 is reduced in net amount and changed in regard to the predominating organisms.

Beaver River.—Samples from the Beaver River show a varying and rather abundant plankton made up of a well-balanced variety of forms and contributing from 4 to 13 per cent of the total catch.

Diatoms appear in every catch and are relatively abundant in eight catches, forming from 17 to 86 per cent of all organisms in the respective catches, the larger values being confined, with one exception, to the cooler temperatures of the last four weeks, September 15 to October 15. *Synedra delicatissima* was most abundant, appearing in every sample but one and forming the bulk of the entire catch in the last four samples, seemingly favored by the cooler weather. *S. biceps* and *S. ulna*, the latter classed by Senft (1905) as a pollutional organism, were present in moderate numbers in nearly all samples.

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[1] Not yet published.

Minute green algæ, consisting of fragments of very small filamentous forms together with the unicellular *Pediastrum* and *Scenedesmus*, formed from 2 to 27 per cent of organisms in nearly all the catches. Small amounts of blue-greens were found in four samples. Chlorophyll-bearing flagellates of the Mastigophora, chiefly *Euglena viridis*, *Dinobryon*, and *Phacus*, were present in similar amounts. The diatoms, algæ, and green flagellates thus aggregate a volume of synthetic or plantlike organisms which is somewhat greater than the volume of plankton animals, as will be seen.

Of the plankton animals, *Difflugia*, a bottom rhizopod, was present in two samples, one of which was taken during rising levels and the other following the crest of a rise. Ciliates were represented by *Codonella* and *Tintinnus*, sparingly found in two samples. This scarcity of ciliates, which are usually abundant in contaminated water, is surprising, in consideration of the fact that the presence of pollution is indicated by *Euglena viridis* in a majority of the samples, and a similar organism, *Phacus*, is found in four samples.

Three samples contain the rotifer *Brachionus* in small to moderate numbers, and the contaminate rotifer *R. vulgaris* was found in two samples, but in small numbers. The rotifer *Anuræa cochlearis*, which is not characteristic of great pollution but abounds in water containing only moderate amounts of organic matter, was moderately abundant in 8 of the 10 samples. It is noticeable also that the minute chlorophyll-bearing organisms that form the greatest part of the food of this rotifer (Kofoid, 1904, p. 151) were found in all samples but one.

Crustacea appeared sparingly in two samples only. *Cyclops*, the leading form, thrives best in a stable environment as to water movement. (Kofoid, 1904, pp. 260, 267.) The mild but frequent fluctuations of the Beaver River during this period may explain, in part at least, the scarcity of crustacea. These disturbances of water levels will also explain the presence in four samples of a few nematode worms which normally live in bottom ooze or in decaying matter which would be disturbed by fluctuating movements of water.

The relatively heavy plankton of the Beaver River, averaging 4 to 13 per cent of the average total catch, indicates that conditions are, on the whole, favorable for plankton production. The one unfavorable condition thus far observed is found in the somewhat unstable hydrographic conditions. The fact that this does not seem to interfere with the presence of relatively abundant plankton would seem to indicate that other vital factors of plankton production are at their best, thus compensating in some degree for the unfavorable condition mentioned. It is therefore evident that food, in all probability sewage, is present in considerable amount, and in such stages of decomposition as will best suit the requirements of such organisms as constitute the plankton. Toxic conditions, such as the acidity of water, which apparently limits to a few resistant organisms the plankton of the Monogahela River, are evidently absent from the Beaver River, for a large variety of organisms is included in the list of plankton.

Bottom deposits.—In addition to the samples of water taken for examination, a series of 20 samples of bottom mud was collected for the study of the life upon the bottom of the stream. The samples represented four of the five stations of this district, it having been impossible to obtain any mud at the bottom at Station O–23.

The tubificid worm, *Limnodrilus*, characteristic of sewage pollution, was found at each of the stations, but in increasing numbers with increasing pollution. It was comparatively rare in the Monongahela, and present in great abundance at Station O–3.

Some *Chironomus* larvæ and the associated form *Tanypus* were found occasionally.

In general, results are what might be expected from the known facts concerning the condition of pollution of the waters. The unfavorable effect of acidity is also observed, although here again it can not be stated whether this effect is primary or secondary.

SUMMARY OF BIOLOGICAL CONDITIONS IN THE PITTSBURGH DISTRICT.

The nearly equal urban and sewered populations of the two contributing watersheds tend to produce waters that, without consideration of other factors, upon their arrival at Pittsburgh are similarly contaminated. But the great variation of climatic, physical, and other factors make of the two streams distinctly different biological habitats. Prominent among these differences are geographical position, size of catchment area, slope of valley, detention of water by pools and dams, amount and kind of industrial wastes and mine drainage, and, finally, the distribution of population with reference to the time of flow from the points of pollution to the confluence at Pittsburgh.

The average yield of plankton in the lower Monongahela is considerably greater than that of the lower Allegheny. This condition is ascribed to the long storage period to which the Monongahela water is subjected, and the resulting age of the water, permitting extensive development of plankton life in the nearly motionless waters rich in the accumulated products of decay of organic matter.

But this heavy plankton is limited to a small assortment of organisms, presumably because the acid condition of the water kills off the smaller ones and the less resistant of the larger forms, both plant and animal, leaving to few surviving varieties the very large supply of rich food that must be present in this old and heavily polluted water. The possibility of an acquired immunity having resulted from continuous exposure of successive generations to the acidity of the water is an interesting biological contingency.

The smaller plankton yield of the Allegheny seems to be due chiefly to water movement and consequent frequent replacement of water by that of more recent origin, thus cutting short the time period required for plankton production and for the requisite degree of decomposition of organic matter which results in suitable food for plankton organisms.

The waters, on combining, are subjected to a further time period of two to four days in reaching Station O–3, receiving in the meantime a large amount of sewage and of various industrial wastes along the Pittsburgh water front. The plankton at this station is not as large as conditions of food supply and time-factor seem to warrant, the discrepancy being due, in all probability, to the presence of harmful substances among the numerous industrial wastes discharged into the river. Before O–23 is reached Dams Nos. 1 to 5 have impounded the water for an additional period of 5½ to 12 days. The resulting plankton at O–23 is reduced in net amount and changed in character.

Organisms at M–12 can hardly be regarded as characteristic of pollution, except one rotifer (*R. vulgaris*), which is so classed by Eyferth (1909) and was found in 7 of the 10 samples.

The small amount of plankton at A–7 exhibits a varied assortment of organisms which do not, as a whole, indicate pollution. One distinctly pollutional organism is relatively abundant in one sample and is present in a second.

In plankton from O–3 distinctly pollutional and contaminate organisms are present in every sample but one.

Plankton from O–23 shows known pollutional organisms in two samples. The presence of the cleaner water rotifer *Anuræa* in four samples, together with the decline of rotifers as a class and the corresponding increase of crustacea, are significant of some improvement in the water since leaving Station O–3.

The Beaver River yields an abundant and well-assorted plankton, in which diatoms predominate. The rotifer *Anuræa* is found in most samples. Pollutional organisms are present in moderate and small numbers in 8 of the 10 samples.

Mud samples give throughout evidence of pollution.

Table No. 3.—*Organisms of bottom mud as a pollution index of Ohio River.*

District.	Sampling station.	Time interval included.	Number of mud samples 200 c. c. each.	Pollutional organisms.		Doubtful and indifferent organisms.	
				In all mud samples; total number.	Average per sample.	In all mud samples; total number.	Average per sample.
Pittsburgh	M-12	August to Oct. 15, 1914	4	[1] 12	3	0	....
	A-7	do	5	189	38	14	3
	O-3	do	5	2,909	582	4	1
Wheeling	No mud found.						
Portsmouth	349	August to Oct. 15, 1914	4	22	5	10	3
	358	do	4	10	3	28	7
Cincinnati	461	July 20 to Nov. 20, 1914	9	4	....	22	2
	475	July, 1914, to November, 1915.	61	5,566	91	137	2
	492	September 1914, to December, 1915.	3	36	12	15	5
Louisville	598	do	69	796	12	483	7
	619	September, 1914, to Apr. 30, 1915.	4	80	20	101	25
Paducah	904	September to Oct. 15, 1914,	4	11	3	12	3
	920	do	2	0	....	5	3
	933	do	5	1	....	7	1
The start at	O-3	August to Oct. 15, 1914	5	2,909	582	4	1
The finish at	933	September to Oct. 15, 1914	5	1	....	7	1

[1] Small number of organisms may be due in part to acid condition of water.

THE WHEELING DISTRICT.

The significant features in the biological situation in the Wheeling district are these:

The water from the Pittsburgh district, contaminated with sewage and industrial wastes, with some inhibitory influence by the acid water of the Monongahela, has been exposed to 95 miles of flow, the time interval of which will vary greatly, according to the stage of the river.

Twenty-five miles below Pittsburgh the Beaver River, draining 3,000 square miles, enters the Ohio.

A moderate amount of comparatively fresh sewage and industrial waste from two districts 50 and 70 miles, respectively, below Pittsburgh affects the water.

Sewage and industrial wastes from Wheeling constitute a moderate secondary contamination. This is lessened somewhat by the preliminary treatment afforded a portion of the sewage and slaughterhouse refuse by the septic Wheeling Creek.

Dam No. 13 forms an 11-mile slack-water basin extending along the Wheeling water front and several miles above the city. A population of about 75,000 contributes untreated sewage. Industrial wastes, consisting of slaughterhouse refuse, waste from steel mills, and some mine drainage, are discharged along both sides of the water front. Most of the slaughterhouse waste is first discharged into the backed-up water of Wheeling Creek, which is bubbling and offensive in consequence of the septic action resulting.

Three sampling stations were utilized in the study of the waters of this district. The upper station, O–65, is 40 miles below the mouth of the Beaver and 25 miles above Wheeling; the middle station, O–77, lies between Steubenville and Wheeling; and the lower station, O–97, is at the lower end of the basin formed by Dam No. 13 and about 6 miles below Wheeling, all in slack water at low river stages.

Samples were taken at weekly intervals from each of these stations during August, September, and October, 1914. The hydrographic conditions were unusually stable. The average results of these examinations are recorded in Table No. 1, page 14, and the principal features are shown graphically in planktograph No. 2.

Station O–65.—This station yielded a moderately light plankton containing few pollutional organisms, but with crustacean scavengers rather abundant.

The Beaver River and East Liverpool, 20 miles above this point, constitute the only recent pollution. The Beaver River increases the volume of the Ohio by about 10 per cent and contributes a heavy plankton made up of a varied assortment of organisms. After 40 miles of flow and with these influences at work the station under consideration yields a plankton which differs from that at Station O–23 in being less abundant and in showing better biological balance.

Three dams are located in the stretch between the mouth of Beaver River and Station O–65. The impounding action is accentuated by the low water levels prevailing in the Ohio River during this period.

The hydrometric studies show that the mean time interval between O–23 and O–65 during 1914 was 4.9 days in August, 6.14 days in September, and 11.35 days in the first half of October.

Station O–77.—The important features of the results at Station O–77 as contrasted with those at Station O–65 are the greater abundance of plankton, the increased proportion of crustacea, the higher numbers of diatoms and lower numbers of algæ, and the regular occurrence in small numbers of *Euglena viridis* of recognized pollutional habitat.

The two stations are essentially similar in regard to the organisms that predominate. In both, diatoms lead, except in August at Station O–77, and crustacea are abundant, exceeding the rotifers in total volume.

The relatively large amount of plankton is significant, considering the fact that thus far there has been a successive and consistent decrease as the Stations O–3, O–23, and O–65 are reached. It is indicated, therefore, that the steady decrease in plankton content noted in the upper stations was due to food exhaustion, and that this decrease has been temporarily arrested by the addition of a considerable amount of sewage from Steubenville and Wellsburg.

Station 0-97.—Notwithstanding access of sewage and industrial waste from Wheeling and the slight impounding action of Dam No. 13, plankton at O-97 showed a decrease, instead of an increase, as compared with plankton from O-77.

Differences in the biological balance and in the predominating organisms give somewhat uncertain evidence of the activity of some unfavorable factor which may be responsible for the lack of normal increase in plankton.

Few pollutional organisms are present. Crustacean scavengers are abundant, however. Cleaner water organisms are moderately abundant.

Bottom deposits.—Repeated dredgings at each of the stations of this district failed to bring to the surface anything but clean sand and gravel.

SUMMARY OF BIOLOGICAL CONDITIONS IN THE WHEELING DISTRICT.

At O-65 the relatively light plankton indicates the gradual exhaustion of available food since leaving the last Ohio station at O-23. Thus, despite added pollution from the Beaver River and from East Liverpool, biological purification of the river is well under way at this station, only 65 miles below Pittsburgh. This fact is further shown by the character of the prevailing organisms. Pollutional forms which indicate recent addition of sewage (ciliates and certain flagellates) are few in number, while organisms which are equally characteristic of the presence of old and relatively stable organic matter (diatoms and crustacea) are abundant.

Another matter that speaks well for the betterment of the water is the appearance, for the first time in the Ohio, of biological balance among the plankton organisms. This means a considerable assortment of food materials in various stages of disintegration which permits the existence of a large variety of forms well distributed among holophytic, or plantlike, and holozoic, or animallike, organisms. Biological balance also means absence of any particularly destructive agency, such as toxic material. It means also the presence of such amounts of sunlight, of dissolved gases, and of dissolved salts as may be required for those plantlike organisms which constitute the first links of what Kofoid calls "chains of food relations," the succeeding and final links of which are made up of higher animals.

The Wheeling district as a whole represents the stabilizing of the water as expressed in the prevailing biological balance. As the water leaves this district on its 250-mile trip to the next sampling station it is in more nearly normal and stable condition, judged from a biological point of view, than when it left Station O–23 in the Pittsburgh district.

THE PORTSMOUTH DISTRICT.

Portsmouth is located at the confluence of the Scioto with the Ohio, 355 miles by river below Pittsburgh. Between Wheeling and Portsmouth, a distance of about 265 miles, the Ohio receives comparatively little sewage pollution either directly or through its three tributaries of consequence, the Muskingum, the Kanawha, and the Big Sandy. These three tributaries, together with several smaller ones, increased the volume of water in the Ohio by about 167 per cent between Wheeling and Portsmouth during the period covered by these examinations.

At Portsmouth the Ohio receives the sewage of the city (which is insignificant in proportion to the discharge of the river) and also the waters of the Scioto, draining 6,500 miles and bringing sewage from Columbus, Marion, Circleville, and Chillicothe, aggregating a population of 220,000. Columbus and Chillicothe, the points of chief contamination, are 130 and 60 miles, respectively, above Portsmouth.

The organic matter of the water reaching Portsmouth has undergone the effects of time and dilution afforded by the extended flow from the last station and the advent of large tributaries which add comparatively little pollution.

The movement of water from Wheeling is comparatively rapid in a channel which consists of a succession of islands which divide the current, shoals and riffles which spread the water in a thin sheet, bars which deflect the stream from one side or the other, and pools which retard the movement, a natural mixing arrangement typical of the Ohio River. Two dams controlled by locks also assist somewhat in the impounding and mixing process.

Three stations were selected for the biological studies in this district. Station O–349, 6 miles above the city of Portsmouth, is representative of the water previous to its pollution in noticeable quantities. Station O–358, below the city, gave representative samples of the water after passing the city and as affected by the rather extensive pollution of the Scioto. The Scioto itself was further studied at a station located at its mouth.

The average results of weekly examinations in August, September, and October, 1914, are given in Table 6, and the salient features are shown in graphic form in planktograph No. 3.

Station 349.—Collections at station 349 show large reduction in plankton as compared with the results below Wheeling, evidently due to a gradual exhaustion of the food supply. There is also noticeable lack of animal forms and almost total lack of pollutional organisms.

The Scioto River.—It is evident that environmental conditions are more favorable for biological activity in the Scioto than in the Ohio at Station O–349, chiefly in the matter of food supply resulting from the discharge of sewage into this relatively small stream at Columbus, 130 miles upstream, and Chillicothe, 60 miles above the mouth. But even this Scioto plankton yield is light. Animals are only moderately abundant and plants, especially minute green algæ, are unusually prominent. This comparative lightness of plankton and the relative abundance of plant life over animals point to the age of the pollution and the considerable degree of decomposition already reached by the contained organic matter. Very few pollutional organisms were found.

Station O–358.—The plankton at station 358 was very similar in kind and amount to that at station 349, but shows slight increase in total volume, evidently due in part to addition of food from the sewage of Portsmouth, and particularly to the heavier plankton of the Scioto River.

Bottom deposits.—In addition to the water samples that were collected and examined, there were taken in this district four samples of mud from the bottom at each of the Ohio River stations and three from the bottom at the mouth of the Scioto.

All these samples gave essentially the same findings, namely, moderate numbers of *Limnodrilus* almost constantly present, with the larvæ of *Chironomus* and the associated *Tanypus* frequently present. Numerically interpreted the results are consistent with the known conditions of moderate pollution. The physical condition of the samples would also go to confirm this finding.

THE CINCINNATI DISTRICT.

The next stretch of the river at which biological studies were carried on is the section of which Cincinnati is the center. The points of chief interest in determining the biological conditions of this district are briefly summed up as follows: The grossly polluted water of the Pittsburgh district has been subjected to a flow of about 481 miles. The time of flow from Pittsburgh to Cincinnati (stated in monthly means covering the period of this study) was 38⅓ days for August, 1914, 39⅙ days for September, and 73½ days for the first half of October. During this interval of flow, tributaries have more than quadrupled the volume of water, and some additional sewage and industrial wastes have been added, notably by the Beaver River, at Wheeling, W. Va., and by the Scioto River. More than 100 miles of flow has intervened since the last appreciable accession of pollution at Portsmouth, Ohio, the time of flow being about three days under the conditions existing during this study.

At Cincinnati the river receives a large amount of sewage and industrial wastes from an aggregate population of over 600,000.

At low river stages Dam No. 37 forms a slack-water basin which extends the entire length of the city water front, providing opportunity for sedimentation and biological action. During the summer and fall seasons of low water, mixing is aided somewhat by the movements of boats.

The stations selected for this study were five in number. Station 461 is well above the city and above the mouth of the Little Miami. The Little Miami at its mouth furnished the second station, and the mouth of the Licking the third. Station 475 is below the major influence of the city and near the lower end of the pool formed by the dam, and 492, the fifth station, is 11 miles below the dam and below the mouth of the Miami. The studies made at these stations were somewhat more extensive than those made higher up the river. The results are given in the form of quarterly averages of the weekly or biweekly examinations in Table 6.

Station 461.—The plankton at station 461 is small in amount and consists of ordinary organisms with a predominance of plant forms, with pollutional organisms practically absent.

The scarcity of pollutional organisms is evidently the biological reflection of the practical absence of recent sewage pollution. Portsmouth, the last point of sewage contamination, is 102 miles upstream, and its contribution amounts to little in the large volume of water. The predominance of plant organisms is likewise to be expected because of the presence of organic matter that is well reduced rather than fresh.

The amount of the plankton, though small, shows a substantial increase over the average amount at station 358, the increased organisms consisting largely of plants.

Stable conditions and low turbidity in November favored plankton development, especially diatoms.

High-water conditions and low temperatures during January, February, and March reacted unfavorably on plankton, resulting in small yield. In addition, many forms are partially dormant during this season. Plankton is necessarily a collection from various tributaries, sheltered backwaters, etc., that have been flushed out by high water.

In April and May, 1915, comparative stability of low levels, low turbidity, and rising temperatures caused some increase in plankton and started the "spring pulse" of diatoms.

June and July, 1915, were characterized by continuous high water and high turbidity. Plankton yield was small.

The Little Miami River.—At the mouth of the Little Miami the autumn samples show a light plankton and a marked degree of biological balance, except during high water. Green algæ, diatoms, rotifers, and ciliates are moderately abundant. Pollutional organisms are found in every sample.

Disturbed hydrographic conditions in December, January, and February resulted in light yield of native plankton and several species of adventitious diatoms. Pollutional organisms were present.

March, April, and May record lower turbidity, less disturbance of levels, and rising temperatures. Plankton yield increased steadily. Pollutional organisms appeared in most samples.

The Licking River.—The apparently erratic data from the Licking River constitutes a reflection of the extreme fluctuations of that stream, due largely to the "quick-spilling" type of its drainage basin. The cutting short of the time-factor by hydrographic disturbances, with the consequent interruption of plankton breeding, results in small yield of organisms and of fewer kinds, even when food supply is sufficient. Another aspect of the matter lies in the fact that rapid run-off and disturbances of level are direct causes of high turbidity which shuts out sunlight and prevents the development of those organisms which require light.

Station 475.—A very few diatoms were present. Algæ were slightly more abundant. The heavier organisms, *Difflugia* and *Tintinnus*, were moderately abundant, a condition to be expected when turbidity is high. Nematode worms were abundant in one sample following excessive turbidity. Pollutional organisms were *Anthophysa* in three samples, and small numbers of the rhizopod *Actinophrys* and the flagellate *Euglena* in one sample each.

The year's regimen of the Ohio at station 475 as based on the weekly plankton samples shows stability and low turbidity in the autumn and again in the spring. Fluctuating levels and high turbidity characterized the other seasons. A well-defined seasonal increase of plankton is found in the spring and another in the fall, the latter consisting chiefly of diatoms. Predominance of plantlike organisms during periods of hydrographic stability, and of diatoms during the disturbed hydrographic conditions of winter months, and an abundance of animals, especially the bottom forms, during times of high water and of marked turbidity, are also noted.

Pollutional organisms were present in a large majority (82 per cent) of all of the samples, most of these containing two or more forms of recognized pollutional animals or plants.

The results at station 492 are characterized chiefly by the marked increase in plankton yield during the fall over the yield at station 475. Few pollutional organisms are present during this period of quiet levels. Biological balance is in evidence. The very heavy plankton was due largely to diatom growth. High water and excessive turbidity resulted in a light plankton during the winter." Favoring environment and seasonal influences resulted in an increase of plankton in the spring, during which time the "spring pulse" of diatoms occurs. The varied assortment of organisms shows some biological balance, but diatoms predominate. Pollutional organisms appeared in six of the eight samples. Continuous high water and excessive turbidity during June and July resulted in small plankton yields.

Bottom deposits.—Nine mud samples were secured from the bottom at station 461 during the period August to November, 1914. Of these, 3 contained no organisms, 2 a few *Limnodrilus*, 4 an average of 5 May-fly larvæ each, 2 a *Tanypus* larva, and a single *Ceratopogon* each.

At station 475, 84 bottom samples were collected during the period July, 1914, to December, 1916. From July to December, 1914, 33 of the 35 samples taken were mud, the remainder being sand with some slight admixture of mud. During the relatively high-water period of January to July, 1915, only 23 per cent of the samples were mud, and during the succeeding period of more stable conditions of flow, July to December, 1915, there was increasing deposition indicated by the fact that 57 per cent of the 23 samples were of mud, either wholly or in greater part. (See Chart No. 17.)

The most numerous organisms in the mud samples from this station were *Limnodrilus* and young bivalves, each of these forms being present, sometimes very abundant, in 33 of the 60 samples which contained mud. Not a sample during the first period was free from one or the other, while most of these samples contained both in abundance. The numbers were considerably smaller during the second period, when the bottom deposits were being swept away by high water, and during the third period no bivalves at all were found in any of the samples. High water had evidently removed them. The worm, *Limnodrilus*, would be less likely to be swept away in toto because of its well-known habit of retreating quickly into its burrow upon any disturbance. The mud must be removed in large quantities to dislodge them.

Other organisms present were *Tubifex*, *Æolosoma*, *Anthophysa*, and *Chætogaster* of the pollutional and contaminate forms. Of the indifferent and doubtful forms, *Chironomus* larvæ were the most abundant, occurring in 13 samples, usually in small numbers. Occasional samples of water snail (unidentified), leech, bryozoa, and larvæ of dragon fly (*Odonota*) and May fly (*Ephemera vulgata*) were found; also a single specimen each of sponge, planarian, and larvæ of *Corethra* and of caddis fly.

Bottom samples were taken at station 492 twice a month from September, 1914, to December, 1915. They showed that very little mud can accumulate in this part of the river under normal conditions. Of the 49 samples only three consisted of mud, and these three were all taken during the unusually stable conditions in the latter part of 1914. All other samples consisted of clean sand and gravel.

Organisms in these samples consisted of *Limnodrilus* and young mussels chiefly. One *Chironomus* larva and one May-fly larva were found. The sewage worm referred to and young mussels were numerous in one sample. The other two samples showed these organisms in moderate and small numbers, respectively.

TABLE NO. 4.—*Bottom sediments at station 475 as affected by river levels.*

	Time included.	Condition as to water levels.	Composition of samples.					Sanitary index of such samples as contained mud.				
								Pollution.				
			Mud.	Mud and sand.	Sand.	Sand and pebbles.	Total number.	Abundant.	Moderate.	Doubtful.	Absent.	Total.
I.......	July to December, 1914..	Unusual stability.......	33	2	....	....	35	30	5	....	....	35
II......	January to June, 1915...	Disturbed levels.........	6	6	8	6	26	11	1	....	....	12
III.....	July to December, 1915..	Moderate stability.......	8	5	8	2	23	10	3	....	....	13
	Total............	....	47	13	16	8	84	51	9	....	....	60

SUMMARY OF BIOLOGICAL CONDITIONS IN THE CINCINNATI DISTRICT.

The principal biological facts of interest are shown in graphic form in the planktographs Nos. 4 to 8, and the general conditions may be summarized as follows:

The river on arriving at station 461 has, during stable conditions, over four times the discharge found at Pittsburgh. The water is reasonably free of organisms associated with pollution, judged by plankton and by bottom mud as well.

The Little Miami adds 2 or 3 per cent of moderately polluted water to the Ohio.

The Licking River, a little larger than the Little Miami, is subject to sudden floods from its quick-spilling watershed. Its water is often turbid and polluted. The frequent flushings carry into the Ohio a quantity of accumulated water and organic matter from the lower 2-mile slack-water portion of this tributary, whose plankton is as erratic as its unstable hydrography.

Station 475 is just below Cincinnati, whose aggregate population of 595,000 has discharged its sewage into the river along a water front of about 12 miles above this station. Dam No. 37, located 6 miles below, forms a 21-mile pool which includes all of the city water front. Plankton, as compared with that of Pittsburgh, is light at station 475, and pollutional organisms are present in moderate numbers. This small yield is the natural result of the larger volume of water (four times that at Pittsburgh), into which a little more than one-half as much waste is discharged, thus making the relative sewage dilution about one-eighth that at Pittsburgh. Also the time period for biological action (about one day) is too short for production of plankton in quantity. Biological balance is apparent.

Mud samples at this station indicate the presence of large amounts of organic matter.

The Miami River, joining the Ohio below Dam No. 37, adds about 5 per cent to the volume of water. Its plankton is light as a rule. It exhibits marked biological balance when conditions are favorable for plankton development.

Station 492 yields a plankton averaging about three times as heavy as that at station 475. This increase seems due to the lengthening of the time factor to two days or more. Biological balance is exhibited. The bottom deposits are scarce on account of strong current.

Seasonal fluctuations shown alike by the main stream stations are:

Very light plankton yield during low temperatures of winter, when water is high and turbidity excessive.

Heavy yield of organisms, especially plants, when turbidity is low and water quiet, even during cool weather.

Presence of bottom organisms in the plankton during time of flood.

Marked diatom pulse in November and a smaller one in April or May.

The situation at Cincinnati is very much simpler than at Pittsburgh. At the latter place two unequal tributaries unite their differing and contaminated waters to form a stream which is heavily polluted by the sewage and industrial wastes of Pittsburgh.

At Cincinnati a relatively normal water suffers a secondary contamination, which is proportionately about one-eighth as heavy as the initial pollution at Pittsburgh.

The noticeable differences in the biological results in the Cincinnati district are: Lighter plankton, fewer pollutional organisms, and greater evidence of biological balance.

The light plankton yield is evidently a result of the relatively smaller amount of contamination.

The prevalence of a condition of biological balance among the organisms constituting the plankton at the several stations in the Cincinnati district, especially at 475 and 492, is evidence of the prevalence of natural conditions; that is, adequate food supply and absence of toxic substances or other destructive agencies.

THE LOUISVILLE DISTRICT.

The water arriving at this district has been subjected to 130 miles of flow since leaving Cincinnati. This includes a period of quiescence and sedimentation in two pools formed by dams. The Kentucky, a tributary of medium size, has added water containing but little sewage. Aside from this there has been no material addition of pollution since the water passed the mouth of the Miami.

At Louisville the water is thoroughly mixed by 2 miles of rapids. In addition to the mechanical aeration, the dissolved oxygen of the water is increased during the season of plant activity by the vigorous growth of submerged aquatic plants in many acres of shallow water above and over the rapids.

Sewage from a population of over 300,000 and large quantities of industrial wastes and stockyard refuse are discharged into the river along several miles of water front.

Two stations were established in the Louisville district for the biological studies; namely, at 598 and 619. Station 598 is at the intake of the Louisville water supply several miles above the direct effect of the city pollution, and at all times within the slack water behind the Louisville dam. The time of passage from the last station of the Cincinnati district, station 492, is shown in the hydrometric studies to have averaged 7.7 days in September and 17.8 days during the first half of October, 1914. Station 619 is below the rapids and below the full effect of the city pollution. At this station samples were taken at three points across the river to determine the effect, if any, of incomplete mixing of the pollution. The effect was not sufficient to justify separate tabulations of the results which are therefore averaged in the tabulated summaries. During the period of these studies the hydrographic conditions were somewhat disturbed in September, but constant at low levels during the first half of October, after which a further period of disturbance during November was followed by stable conditions up to the time of the high water, which lasted through the winter months. Quiet levels prevailed during the early spring, to be succeeded by flood conditions in June and July.

The results of the weekly examinations are given in the form of bimonthly averages in Table 6, and the more important items are shown graphically in planktographs 9 to 12.

Station 0-598.—Summarizing briefly, the 11 months' collections at this station go to show the same seasonal variation and effects of disturbed hydrometric conditions as have been previously pointed out.

The beneficial influence of the long pool above Louisville is evident in that the time period thus imposed on the water results in prolonged sedimentation and biological activity. The approaching end reaction of the latter in the form of large numbers of crustacean scavengers attests the considerable degree to which organic matter has been "stabilized" or reduced toward a condition of comparative harmlessness.

Stable conditions in the fall permit heavy plankton production which includes the fall "pulse" of diatoms.

High water, excessive turbidity, and low temperatures combine to check plankton growth until spring, when warmer water and stable conditions result in moderately heavy yield of organisms, including the spring "pulse" of diatoms and some pollutional flagellates. The disturbed conditions prevailing in early summer resulted in a plankton yield that was light and contained very few plants but many bottom organisms. Pollutional organisms were not especially abundant at any time during the 11 months.

Of the 47 samples taken, 17 were obtained during prevalence of stable conditions and low turbidity and the remaining 30 during flood conditions. Of the former, 18 per cent contained pollutional organisms in relative abundance, while of the latter samples 27 per cent contained these organisms in similar numbers. This would seem to indicate that flood waters, moving rapidly from flushed-out margins and tributaries upstream, arrive at station 598 with a greater number of pollutional organisms than are normal to the environment of this station during stable conditions. Hence, these high-water samples are not a reliable index of local conditions at this station, except in so far as they represent the flood conditions to which the river is subject during a part of each year and the consequent pollution of water incident to this flushing out of margins and tributaries.

Station O–619.—The collections at station 619 were characterized by somewhat lighter plankton content, the difference being chiefly due to the smaller numbers of crustacea present. It has been observed elsewhere in these studies that the crustacean *Cyclops* seeks the more quiet waters and appears by reason of its powers of rapid movement to be able to avoid, in large part at least, being drawn into the swifter currents. Some laboratory tests of the possible speed of locomotion of these small organisms showed for 13 specimens an average speed of 1.2 inches per second. Pollutional forms were noticeably more prevalent at this point than above the city, although their actual numbers were small, a fact to be considered in connection with the very brief time of passage to this station from the actual points of discharge of the city wastes.

Bottom deposits.—Eighty-seven samples of bottom deposits were taken at station 598 during the period September, 1914, to December, 1915. Of these, 69 were of mud, 14 of sand with traces of mud, and 4 of clean gravel or pebbles only.

At this station also, as at 475, the presence or absence of mud on the stream bed is essentially a function of water movements. The mud accumulates when conditions of stream flow are stable; it is partially or entirely swept away by floods, and again accumulated with the return and continuance of hydrographic stability.

The prevailing type of sample from this station is characterized by light or yellowish color, little or no odor, and rather granular consistency, indicating the presence of a relatively small amount of organic matter.

A few samples, however, show some of the conditions associated with pollution. Seventeen of the 69 samples contained an average of 28 tubificid worms (*Limnodrilus*) and 6 young bivalves per sample. The corresponding numbers of these organisms usually associated with pollution averaged considerably greater at station 475; namely, 81 worms and 23 bivalves per sample. This was true of 51 of the 60 samples which contained mud, as compared with the much smaller ratio of 17 out of 69 mud samples at station 598.

Such other pollutional forms as *Chætogaster*, *Æolosoma*, and mats of *Anthophysa* appeared frequently in the samples from 475, but never in those from 598.

Forty-three samples from this station showed pollutional organisms in moderate or small numbers and organisms of cleaner habitat in large numbers, thus indicating the presence of organic matter in moderate amount. Seven samples contained chiefly those organisms that are not associated with pollution.

Out of 35 bottom samples collected at station 619, only 4 contained mud, the current at this point being strong enough during most of the year to prevent deposit of suspended matter and silt. Three of these samples contained pollutional organisms in sufficient numbers to indicate presence of organic matter in large amount. The fourth showed moderate pollution only.

TABLE NO. 5.—*Physical and biological status of bottom sediments from stations Nos. 475 and 598.*

Station.	Number of samples.	Time included.	Color.		Odor.		Consistency.		Pollutional organisms.		Summary—Average number.	
			Dark to black.	Light or yellowish.	Offensive or stagnant.	Slight, not offensive.	Soft, sticky, and slimy.	Somewhat soft, granular, or tough.	Abundant.	Moderate number or few.	Showing strong pollution.	Showing moderate and light pollution.
475	47	July, 1914, to December, 1915...	39	8	42	5	37	10	39	8	39	8
598	60	.....do	25	35	13	47	18	42	15	45	18	42

SUMMARY OF BIOLOGICAL CONDITIONS IN THE LOUISVILLE DISTRICT.

In flowing the 108 miles from Cincinnati to Louisville the water of the Ohio is retarded by slow movement through a long pool whose lower end is at Louisville. This pool is a factor of importance because of its impounding action, resulting in a time period sufficiently long, during low water, to permit decomposition of organic matter to such a degree that crustacea find here ample food supply and quiet environment. These organisms multiply accordingly. Their presence in numbers is significant of the completion of the earlier stages in the process of reducing sewage or other waste matter to a condition of comparative stability and reasonable safety from a sanitary point of view.

Bottom samples confirm, in general, the evidence of plankton samples to the effect that organic matter, though present, is not especially abundant, and that the first stages of decomposition have been completed.

This water, of fairly good quality, now receives contaminating material from Louisville. Pollutional organisms have developed only in small numbers when station 619 is reached. Mud samples, however, show the presence of organisms associated with pollution.

THE PADUCAH DISTRICT.

The river at Paducah is approximately nine times as great in volume as at Pittsburgh. During the flow of 320 miles from the last point of considerable contamination, Louisville, four rivers, the Green, the Cumberland, the Wabash, and the Tennessee, have contributed their waters. Two of these streams, the Wabash and the Tennessee, are of large size. These tributaries have no record of recent pollution. The main stream itself receives direct contamination only from Evansville, Ind., with 70,000 population, 130 miles above Paducah, but in the large volume of water the sewage thus received is negligible. This lower portion of the Ohio watershed is but thinly populated, as a rule. Finally, the sewage from the small city of Paducah (24,000) adds no appreciable burden to the river.

Samples were collected at station 904, above the mouths of the Tennessee and the Cumberland, at the mouths of each of the rivers, at station 920 opposite Paducah, and at stations 926 and 933 below the city. The studies at these points were confined to the months of September and October, 1914. The results are summarized in Table No. 6 and the more important facts are shown graphically in planktograph No. 13.

At all stations moderately high turbidity prevailed and levels were somewhat unstable during September. These conditions were improved in October.

Plankton at all stations was small in amount at all times. September samples yielded a very scant plankton, but decided increase was the rule in October samples, except in the Tennessee River and the main stream station which it immediately influences.

The biological balance of organisms is noticeable at all main stream stations, especially at station 933. This condition is best developed in October. Organisms associated with pollution were sparingly present or were absent altogether. This speaks well for the status of the water as it proceeds on its way from the Paducah district. The balanced and uniform distribution of organisms is a sort of biological democracy wherein competition for food is brisk and aggressive, but no member of the community of organisms is sufficiently powerful or numerous to accomplish the extinction of other classes and to overthrow the existing mutual adjustment of aquatic life. Such a condition of balance has uniformly been noted in those sections of the river in which biological self-purification of the water has proceeded nearly to completion and is perhaps the best evidence of the prevalence of natural conditions and of the absence of toxic wastes or of other abnormal and destructive agency.

Six samples of bottom sediment, two of which consisted of clean sand, were taken at station 904 during September and October, 1914.

Two samples contained young mussels in small numbers. These organisms are so persistently found under conditions of heavy pollution that their place seems to be with, or very near, the pollutional organisms, particularly when they occur in large numbers.

Four samples of deposits taken in September and October, 1914, well up the mouth of the Cumberland River, contained organisms of indefinite habitat, and two samples taken at station 920 in September, 1914, gave similar indications.

Five samples taken well up the mouth of the Tennessee River during September and October, 1914, showed small numbers of tubificid worms, and young mussels appeared in three. Organisms of doubtful significance were found in small numbers in the others.

Five bottom samples were taken at station 933 during September and October, 1914. Organisms were few except in one sample, which yielded larvæ of *Chironomus* and of May fly.

SUMMARY OF BIOLOGICAL CONDITIONS IN THE PADUCAH DISTRICT.

The decreased yield of plankton in the Paducah district is evidently due to the small amount of organic matter present and to dilution by tributaries.

Scarcity of the organic matter which serves as food supply, either direct or indirect, for most plankton organisms may be credited to a number of factors which combine to produce this result. The water on leaving the Louisville district did not contain a great amount of waste, for, notwithstanding the considerable quantity contributed here, the volume of water is so great that the relative contamination is small when compared to that at Pittsburgh. By the time the water arrives in the Paducah district its volume has been further increased by tributaries and only an inconsiderable amount of additional waste has been received. Meantime the various purification agencies, biological as well as chemical and physical, have reduced much of the organic matter, leaving scant food supply for the diminishing plankton.

Dilution by tributaries is also a factor. Those tributaries from which data are available tend to dilute, instead of to concentrate, the plankton of the main stream. This means that conditions of contamination and of subsequent purification are so related in these tributaries as to result in a lower plankton content in the tributary than in the main stream.

GENERAL SUMMARY OF BIOLOGICAL INVESTIGATIONS.

The outstanding charateristics of the Ohio River which definitely influence its biological content are mainly as follows:

The Ohio constitutes a kind of natural "Mason and Dixon's line." Tributaries from the north are affected by rigorous winter conditions, and the spring thaw unloads in their waters large amounts of organic matter which have accumulated during the colder weather. Tributaries from the south experience much milder winter conditions. The streams are not icebound, as a rule, and the contained organic matter is disposed of by purification processes which, on account of the higher temperatures, may proceed to advantage from the time the sewage or other waste enters the water. Such a tributary brings to the main stream a water whose organic matter has been disposed of to a degree which is impossible for the cold waters of the northern tributary.

The adjustment of these differences by the mingling of the waters in the main stream produces situations which are biologically important because of the continuous variation in amount, kind, and degree of decomposition of the food supply thus brought by these tributaries.

Geologically speaking, the river is young. It has not yet reached grade, and consequently a large amount of erosion is taking place. This expresses itself in the frequent and high turbidity, which in turn becomes a factor of much significance to holophytic (plantlike) organisms by depriving them of sunlight and checking their growth. These minute plants constitute much of the food supply of certain animals of the plankton. Moreover, these plants produce oxygen in the water by photosynthesis.

The presence of many riffles, pools, bars, and islands constitutes an effective mixing apparatus which hastens the adjustment of differences that are imposed anew by each tributary, or sewered town, or drainage from industrial establishments. Continuous variation of speed, of depth, and of relative surface exposure is experienced by the moving water. Aquatic organisms requiring different degrees of water movement, of light, or of concentration of organic matter thus find conditions to their liking, and the biological expression of these various conditions is seen in the great diversity of plants and animals which constitute the Ohio River plankton.

High floods occur in spring, and frequently at other seasons. Currents are swift and the water speedily traverses the length of the river. During a relatively dry period the water is quite low and seems almost motionless in the larger pools. These extreme fluctuations cause enormous variations in the time of flow, with resulting disaster or advantage to most plankton and mud organisms which, as a rule, flourish in proportion to the degree of stability and quiet in their environment.

Numerous dams serve to impound and conserve water during dry weather and to increase the volume of water for the reception of sewage or other waste. The time-factor is thus increased also, to the advantage of plankton organisms in the matter of breeding and in the better decomposition of organic matter which provides food for these organisms.

Organic matter of many kinds, introduced mainly in the regions of Pittsburgh, Cincinnati, and Louisville, constitutes the chief reason for the existence of most of the Ohio River plankton and certain of the mud organisms as well, which find abundant food and favorable environment in the conditions thus created near the main points of pollution. Smaller amounts of polluting material introduced at various other points serve to reproduce to some degree the conditions which encourage plankton life on a large scale at the three places of heavy pollution.

An abnormal condition of the water, such as the acidity of the Monongahela River, is reflected by an abnormal condition of the plankton and aquatic life in general. The apparent effect on the aquatic organisms is the killing off of certain of them, either by first removing their food supply of bacteria, as in the case of many ciliates, or by direct unfavorable action of the acid on the cell contents of the organisms concerned. The aquatic life surviving such abnormal state of the water is limited to comparatively few varieties, although these may be present in large numbers, as in the Monongahela.

Conversely, the persistent yield of an abnormal plankton may be regarded as evidence of the continuous operation of some unusual factor in the local environment.

Each tributary or stream is a law unto itself, because it has its own peculiarities of stream flow, degree of contamination, temperature conditions, and other controlling factors. Nevertheless, within broad limits, many streams are much alike, and the biological reflections of their predominating characteristics are comparable. The most important items in such comparisons are food supply of sewage and other organic matter, adequate time for breeding of organisms and decomposition of organic matter, and absence of toxic waste or other unduly destructive conditions, the latter including persistent turbidity, which deprives holophytic organisms of light and prevents their activity.

As each separate stream has its own characteristics, so the various portions of any one stream may present a series of conditions which are to some degree related to and yet distinguished from one another. A typical series of differing biological situations is presented by the Ohio and its tributaries. The aquatic organisms respond to the dominating factors, as is shown by the heavy plankton yield restricted to very few kinds of organisms in the Monongahela, the net result of abundant and suitable food, and of presence of acidity which kills off certain forms. The uniform and natural distribution of organisms in the Wheeling district is evidence of the successful elimination of the unfavorable conditions. Predominance just below Pittsburgh, Cincinnati, and Louisville of typical organisms usually associated with sewage pollution is the biological reply to the discharge of sewage from those cities. Similarly, the light yield of plankton at Portsmouth, at station 461, and finally at station 933, the erratic yield of the Licking, the well-balanced plankton of the Beaver, and of the Ohio at certain places, notably at stations 598 and 933; all these are the biological expression of the various interrelated factors that prevail at the respective locations.

The aquatic life at any given sampling station also varies with respect to season and temperature, rainfall, and amount of sunlight. Most of the species of organisms are active only during moderately warm weather. However, if conditions are stable and water is clear enough to admit sunlight, a heavy plankton, principally of diatoms and other minute algæ, is the usual result, even if the temperature is low. This is shown by the high content of diatoms at successive Ohio River stations in November, 1914. A similar pulse of the same organism occurred in November, 1915, and in latter part of August and first part of September in 1916.

Flood conditions obscure the influence of local environment of the plankton, bring organisms from distant points, interrupt favorable conditions of quiet for the local plankton, and cause turbidity which deprives holophytic organisms of sunlight. Bottom organisms are brought into undue prominence, and clear-water forms, such as crustacea, are carried away or dragged to the bottom by silt deposited on their appendages. Flood-time plankton is essentially misleading as to local conditions, and is therefore of questionable value as an index of the biological conditions prevailing at the station in question.

Bottom sediments represent an accumulation of matter, previously suspended in the water. Such deposits constitute an index as to the condition of the water, unless floods or current remove these sediments too often to permit the development of such physical conditions and biological content as will faithfully reflect the local environment. In these respects the bottom deposits fluctuate more slowly and less widely than does the overlying water. As a rule the results of examination of sediments are correlated with the results of plankton examination, and the careful inspection of such deposits is accordingly of importance in the biological survey of a stream.

Biological balance as seen in the Ohio River means the presence of organisms in such number and in such assorted varieties as will successfully cooperate with existing chemical and physical conditions in the effective reduction of the organic matter which may enter the water and in carrying on the continuous flux of this matter from the lowest forms of life to the highest. This includes the work of bacteria, of plankton, and of larger organisms. The presence of organic matter such as sewage results in abundance of animal forms rather than plants (aside from bacteria), while dissolved inorganic matter resulting from advanced decomposition favors the presence of plants as the dominating organisms. The middle ground between these two extremes is characterized by presence of a great variety of both animal and plant forms.

Information concerning the history, present condition, and rate and direction of change of a natural water may be obtained from the results of suitable chemical and bacteriological tests. This information is obtainable from such tests only because of extensive preceding studies, during the course of which correlations have been established and methods of procedure have been modified and adapted to secure reliable information with the minimum of possible error of interpretation. The great majority of these investigations have not, however, included an examination of the plankton and related organisms, nor have the tabulated results accredited anything to the activity of these biological workmen. Inasmuch as these organisms are present (and sometimes very numerous) in practically every natural water, it would seem that an adequate examination of this water must include a study of this ever-present biological factor, for otherwise certain phases of the final interpretation will be open to question. It seems reasonable that correlations should exist between this aquatic life and the degree of pollution and extent of self-purification of the water concerned, similar to the correlations which appear when the bacterial content and chemical condition of such waters are studied. To discover and record these correlations is the first task of the biologists who would continue the investigations begun by Forbes, Kofoid, Haeckel, Marsson, Kolkwitz, Eyferth, and others. To determine by long-continued observation and special laboratory tests to what extent and in what ways this biological factor may affect the bacteriological and chemical conditions, and be in turn affected by them, and the manner in which all these factors, together with the physical features, are mutually related in the process of self-purification of streams is the next group of problems awaiting solution.

TABLE NO. 6.—*Microscopical examination (average results).*

Station.	Number of samples.	Temperature (C.).	Turbidity (p. p. m.).	Gage height (feet).	Organisms and other matter (standard units per c. c.).											Volumetric data (c. c. per cubic meter).	
					Holophytic.[1]			Holozoic.[1]						Total plankton.	Amorphous matter and silt.		
					Diatoms.	Algæ.	Mastigophora.	Fungi.	Rhizopoda.	Ciliata.	Rotifera.	Crustacea.	Vermes, etc.			Total catch.	Plankton.[2]
PITTSBURGH DISTRICT.																	
August–October, 1914.																	
M-12	10	22	5.8	6	3	....	....	....	37+a	5	648 ab	....	8 a	701	10,970	70.65	4.3
A-7	10	19.5	23.8	1.3	39 a	20 a	14	2	34 ab	2	19 a	2	7	139	16,095	133.7	.9
O-3	10	21	15.6	6	8 a	15 b	+	4	6	47 a	504 ab	16	15	615	7,213	54.5	4.3
O-23	10	21	11.2	6	56 a	18 c	7	....	....	10	263 ab	122 a	....	474	8,420	46.25	2.5
Beaver River	10	19.5	18	4.4	329 bc	50 c	61 ab	....	14	8	119 c	14 a	8	601	6,080	61.9	5.3
WHEELING DISTRICT.																	
August–October, 1914.																	
65	9	20	5.3	8.1	130 bde	16 bc	31 b	....	....	3	48 c	69 a	1	298	6,449	39.15	1.8
77	8	21	29.9	7.7	151 ba	10 d	38 bc	....	....	5	64 cd	140 ab	+	408	6,544	48.6	3
88	4	19	31	7.9	122 bcd	11 bc	73 bc	....	+	12	72 ce	89 ac	....	382	8,350	50	2.5
97	10	20	15	8.2	111 ba	7 bc	44 bc	....	2	3	97 ace	147 acb	....	412	7,050	54.25	2.9
PORTSMOUTH DISTRICT.																	
August–October, 1914.																	
349	7	20.7	39	3.3	57 ba	10 bc	5	....	7 a	14 b	....	....	....	93	12,371	64.6	.5
Scioto River	7	21	60	−.3	79 b	74 bce	2	....	2	8 b	21 c	....	....	190	16,971	106	1.3
358	7	21	45	3.2	51 b	17 bc	2	....	17 a	7 b	1	....	5	100	11,912	66.8	.5

[1] Predominating genera are indicated in the respective columns by letters, and are referred to the following key:

Diatoms.—(a) Synedra sp., (b) S. delicatissima, (c) S. biceps, (d) Nitzschia closterium, (e) Asterionella, (f) S. ulna, (g) Navicula, (h) Fragilaria, (j) Nitzschia sigmoidea, (k) Melosira.

Algæ.—(a) Conferva, (b) Scenedesmus, (c) Pediastrum, (d) Raphidium, (e) Oscillatoria, (f) Ulothrix, (g) Eudorina, (h) Vaucheria, (j) Protococcus.

Mastigophora.—(a) Phacus, (b) Dinobryon, (c) Euglena, (d) Trachelomonas, (e) Anthophysa, (f) Chlamydomonas.

Rhizopoda.—(a) Difflugia, (b) Arcella, (c) Actinophrys.

Ciliata.—(a) Vorticella, (b) Codonella, (c) Carchesium, (d) Tintinnus, (e) Paramœcium, (f) Amphileptus, (g) Stylonchia, (h) Epistylis, (j) Opercularia.

Rotifera.—(a) Brachionus, (b) Rotifer vulgaris, (c) Anuræa cochlearis, (d) Distyla, (e) Polyarthra, (f) Synchæta.

Crustacea.—(a) Cyclops, (b) Bosmina, (c) Chydorus, (d) Daphnia.

Vermes, etc.—(a) Nematode, (b) Chironomus larvæ, (c) Macrobiotus.

[2] Computed from standard unit volumes. (See p. 17.)

TABLE No. 6.—*Microscopical examination (average results)*—Continued.

Station.	Number of samples.	Temperature (C.).	Turbidity (p. p. m.).	Gage height (feet).	Organisms and other matter (standard units per c. c.).											Volumetric data (c. c. per cubic meter).	
					Holophytic.			Holozoic.						Total plankton.	Amorphous matter and silt.	Total catch.	Plankton.
					Diatoms.	Algæ.	Mastigophora.	Fungi.	Rhizopoda.	Ciliata.	Rotifera.	Crustacea.	Vermes, etc.				
CINCINNATI DISTRICT.																	
August–October, 1914.																	
461	8	20.7	115	....	149 ba	56 cae	3	....	8	10 b	11 c	....	1	239	17,108	135	1.8
Little Miami River	6	......	40	6.1	34 bf	66 abc	14 d	....	8	18 e	40 ba	....	13	194	20,909	95.7	.87
Licking River	6	52	140	1.7	3	24 g	32 ce	....	29 a	9 h	63 b	6	1	165	29,817	60	.33
475	10	20.5	227	6.2	51 ba	41 cb	21	+	3	45 bch	66 ac	8	26	265	20,635	65.2	.87
Miami River	8	18	67	2.2	41 ag	95 abc	15 cf	2	2	15 db	....	38 a	15 a	225	28,340	102	.66
492	6	19	77.5	6.1	34 b	35 ca	7	....	2	29 bc	18 ca	18 a	1	143	16,625	85.75	1.34
November, 1914–January, 1915.																	
461	12	5.4	44	17.6	396 bce	15 be	27 b	....	....	17 c	23 cf	....	....	478	80,129	172.6	2.4
Little Miami River	11	......	190	8	216 fcgh	17 ae	3	1	10 a	2	....	....	12 a	264	80,306	221.5	.71
Licking River	10	7	166	45	66 a	15 ae	14 e	+	4 a	1	8	....	29 ab	138	171,080	308	.27
475	14	4	190	17.3	470 bce	103 ce	20 e	1	8 b	8 ac	15 a	....	12 a	639	208,232	456.5	2.32
Miami River	6	1	27	3.7	79 a	10 e	5	....	1	7	25 c	....	3	130	57,762	177.5	.42
492	13	5	210	17.7	532 bfc	60 ec	31 e	+	....	16 b	29	....	83 a	753	114,587	439	10.65
February–March, 1915.																	
461	8	4	....	....	44 c	5	1	6	7 a	4	10	....	27 a	105	46,087	191	.39
Little Miami River	8	4	83	8.9	20 cj	10 e	2	....	14 a	8 ba	24 b	....	18 a	95	52,062	173.5	.47
Licking River	9	......	154	5.4	10 ac	5 h	1	1	4 a	2	3	....	32 a	58	58,850	172.5	.21
475	9	4	130	261	25 a	3	....	1	4	3 a	11 bd	9 a	36 a	94	81,622	175.8	.32
Miami River	9	5	31	5.3	43 a	6	1	2	8 a	19 hcj	1	....	28 ac	108	103,044	246	.48
492	9	3.5	103	27.9	31 aj	13 e	....	3	15 a	11	6	2	23 a	105	102,900	279.5	.28
April–May, 1915.																	
461	8	15.5	24	....	502 ef	8 c	26 be	....	0	11 ba	62 ca	....	1	617	35,593	102.6	1.64
Little Miami River	7	17	....	6.2	300 fbj	59 ced	76 fd	....	7 c	38 fg	86 ba	....	6	573	16,286	81.1	2.8
Licking River	7	......	164	3.1	79 fa	40 gc	80 f	....	6	14 b	145 afb	....	28 a	394	111,000	211	1.01
475	7	15	35	12	319 bce	14 ca	9 cf	3	4	17 ab	7 c	....	14	388	17,614	62.2	1.36
Miami River	8	16	29	....	1,143 fce	207 cbj	32 fc	4	8	15 a	118 baf	10 a	24 ac	1,561	42,862	118.2	4.72
492	8	15	119	12.6	469 cbe	46 ec	14	....	29 a	40 hb	35 ac	8	18	658	104,150	187	.18

June-July, 1914.																	
461	10	22	......	......	31 f	22 aecf	7 e	2	20 ae	33 bd	15 c	......	57 a	194	319,298	828	.46
475	9	23	401	16	22 k	29 eac	25 ec	2	35 ab	65 bda	11	5	21 a	213	222,022	685	.65
Miami River	5	......	......	......	5	19 b	3	......	52 a	41 b	18 c	1	20 a	159	250,900	767	.49
492	9	23	668	17.3	17 k	19 c	14 e	3	19 a	20 ab	34 c	......	18	144	323,511	888	.42
LOUISVILLE DISTRICT.																	
September-October, 1914.																	
598	9	21	71	5.4	21 b	68 a	1	......	+	24 b	109 ca	75 a	19	319	6,959	38.7	2.36
619	17	20	89	5.2	28 b	88 ac	49	2	3	29 b	44 c	3	7	252	9,052	894	1.48
November, 1914-January, 1915.																	
598	14	5	239	18.1	422 bcj	28 afc	32 e	4	29 a	161 b	35 bcd	2	21 a	734	171,402	546.5	3.76
619	24	19	23	16.5	464 bea	34 ea	46 de	+	44 a	10 b	23 ab	3	13 a	638	167,999	450	2.52
February-March, 1915.																	
598	9	4.3	148	26	21 a	3	13 e	......	47 a	1	1	......	36 a	124	146,511	336	.3
619	18	4	150	20.9	22 a	2	5	......	38 a	3	......	......	38 a	109	77,843	301.5	.42
April-May, 1915.																	
598	61	5	17	10	175 ae	25 b	13 f	1	2	8 b	17 c	......	1	243	9,258	44.9	1.21
619	8	14	22	10	248 bae	32 cad	13	......	8	12 b	16 a	......	9	339	11,825	52.5	1.44
June-July, 1915.																	
598	9	24.5	260	161	7	8	5	......	44 a	22 b	15 c	6	18 a	125	143,655	534	.48
PADUCAH DISTRICT.																	
September-October, 1914.																	
904	5	23	100	......	31 b	60 ac	......	......	......	10 b	90 ca	40 a	1	235	14,700	50.5	.87
Cumberland River	4	24	199	......	1	15 e	4	......	20 a	37 d	22 a	......	3	101	11,550	41.2	.3
920	9	23	109	......	47 ba	41 ab	+	......	30 a	37 d	94 a	38 ad	+	289	14,522	47.8	1.08
Tennessee River	6	25	82	......	10	6	2	......	8	37 bd	1	......	3	67	14,050	40.5	.19
926	4	24	132	......	32 ak	32 ab	1	......	12 a	21 b	37 a	......	......	134	12,300	37.4	.4
933	10	23	123	......	20 b	38 a	......	......	10	38 bd	42 a	20 c	4	173	13,820	42.7	.48

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EXPLANATORY NOTE.

In the planktographs which follow all organisms are expressed in volumetric terms of cubic standard units instead of numbers.

Organisms whose life processes are essentially plantlike are classed as Plants, and are plotted in the upper half of the chart. Similarly, organisms whose life processes are essentially those of an animal are classed as Animals, and are plotted in the lower half of the chart.

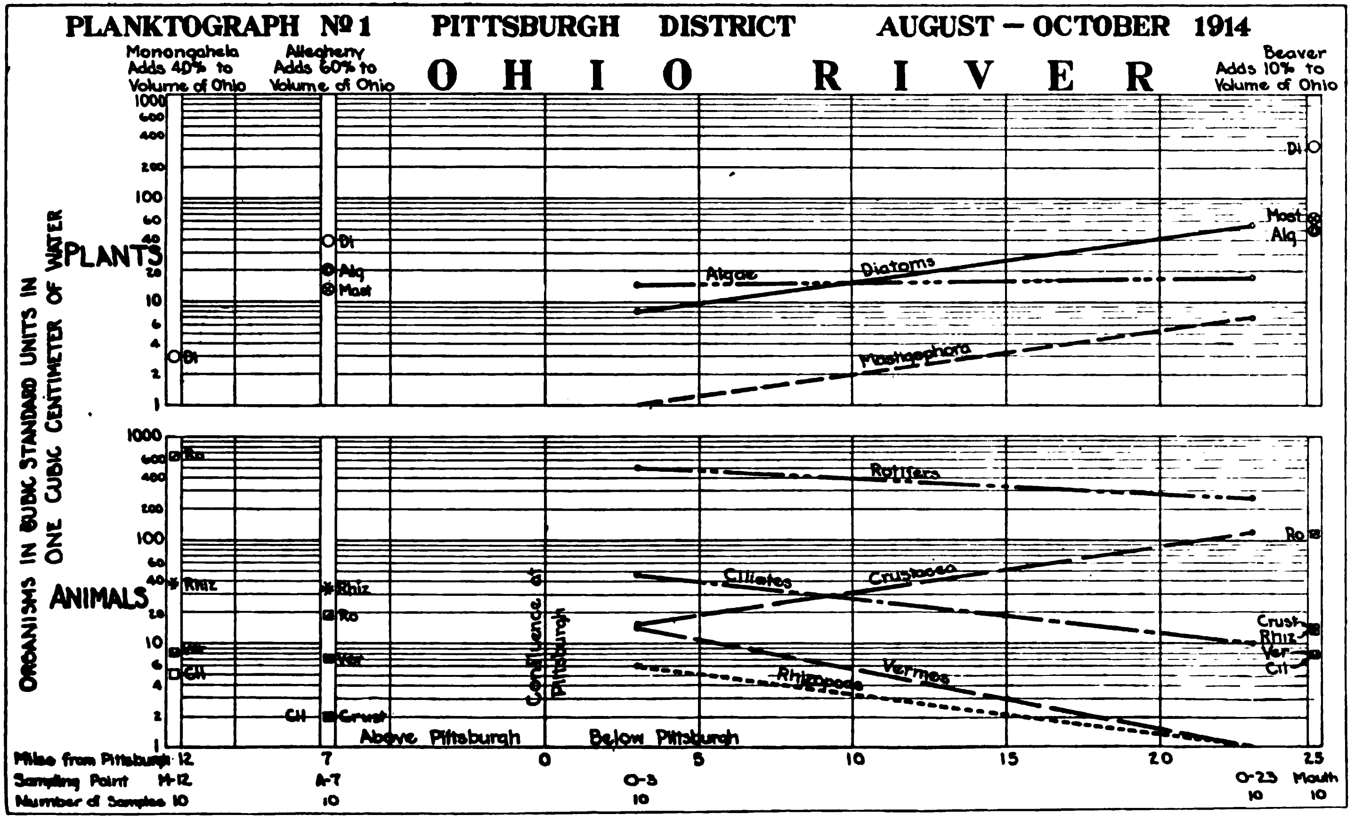
Data of tributary streams are inserted in a narrow vertical space which extends across the chart from top to bottom near the point where this tributary enters the main stream. The various plankton forms are here represented by symbols, with the appropriate abbreviation placed near.

The following abbreviations are used:
Di.—diatoms.
Alg.—algæ.
Mast.—mastigophora.
Rhiz.—rhizopods.
Cil.—ciliates.
Ro.—rotifers.
Crus.—crustacea.
Ver.—vermes.

Data relating to the samples are placed below the diagram proper.

MANNER OF INDICATING ORGANISMS ON PLANKTOGRAPHS.

Organism.	Abbreviation used.	Designating mark for organisms.
Diatoms........	Di........	——————————————————— (Unbroken line.)
Algæ...........	Alg.......	—— . . . —— . . . —— . . . —— . . . —— . . . —— . . . —— . . (Long dash alternating with three dots.)
Mastigophora .	Mast......	– (Short dashes.)
Rhizopoda....	Rhiz......	. . . . (Dots.)
Ciliata.........	Cil........	—— . —— . —— . —— . —— . —— . —— . —— . —— . —— . —— (Long dash alternating with one dot.)
Rotifera.......	Ro........	—— . . —— . . —— . . —— . . —— . . —— . . —— . . —— (Long dash alternating with two dots.)
Crustacea.....	Crus......	—— —— —— —— —— —— —— —— —— —— —— —— —— (Long dashes.)
Vermes.......	Ver.......	—— x —— x —— x —— x —— x —— x —— x —— x —— x —— x —— (Long dash alternating with "x.")



PLANKTOGRAPH No 1 PITTSBURGH DISTRICT AUGUST – OCTOBER 1914

PLANKTOGRAPH Nº 2 WHEELING DISTRICT AUGUST – OCTOBER 1914

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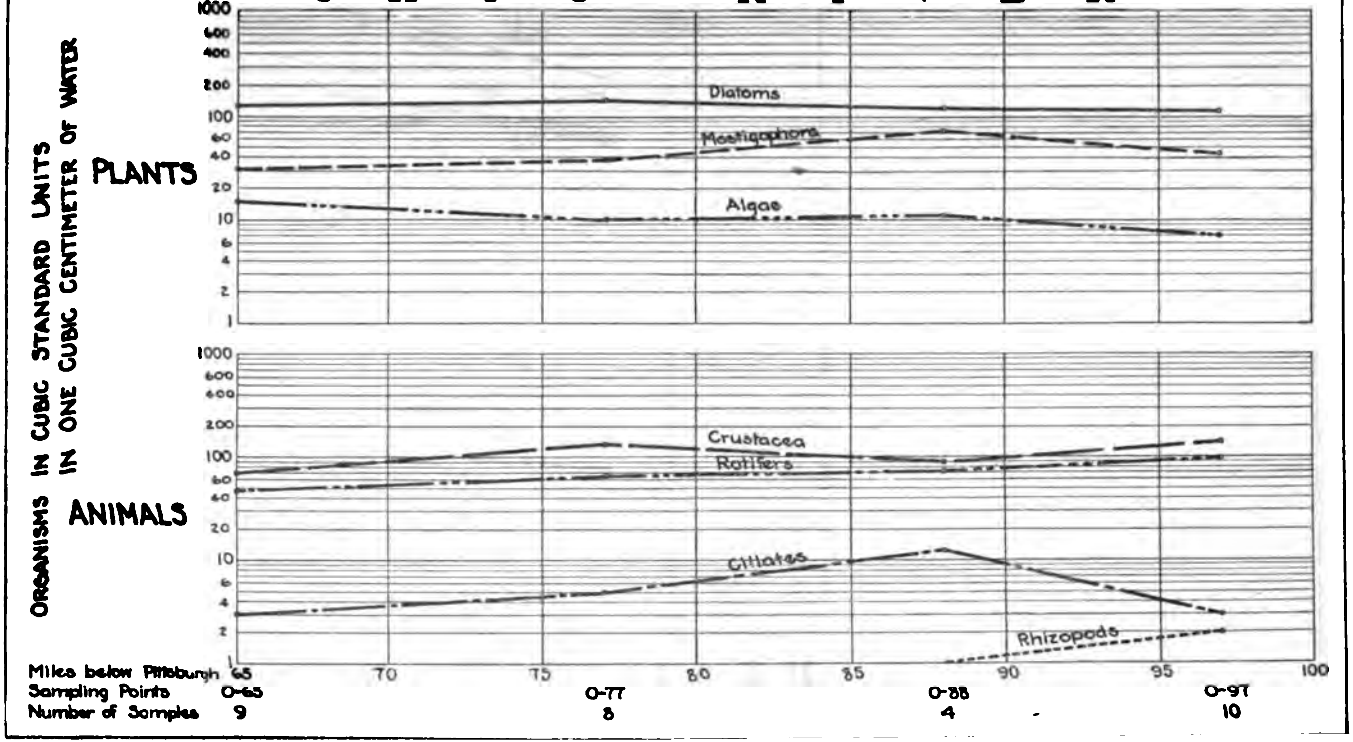
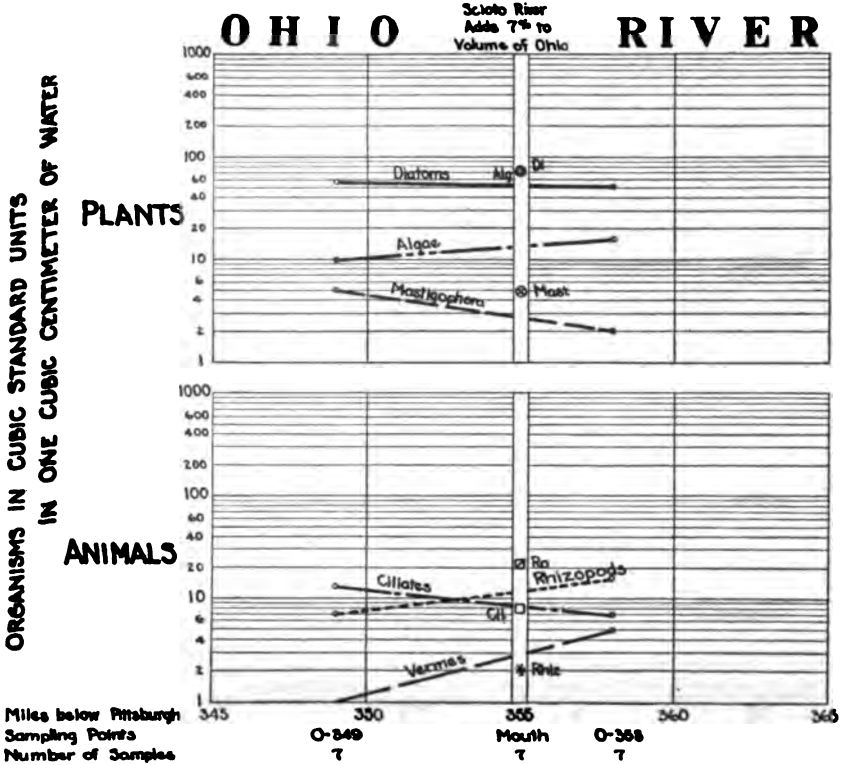
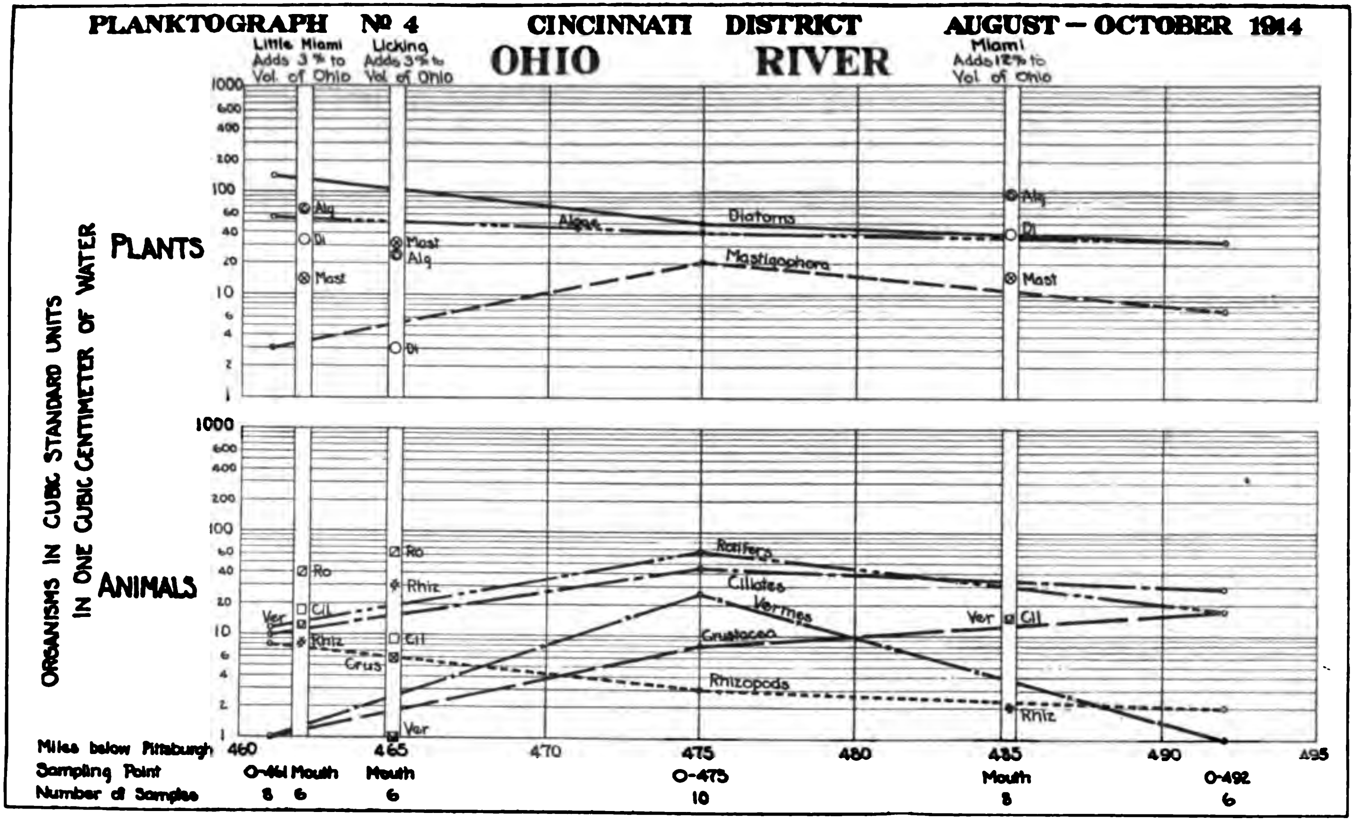
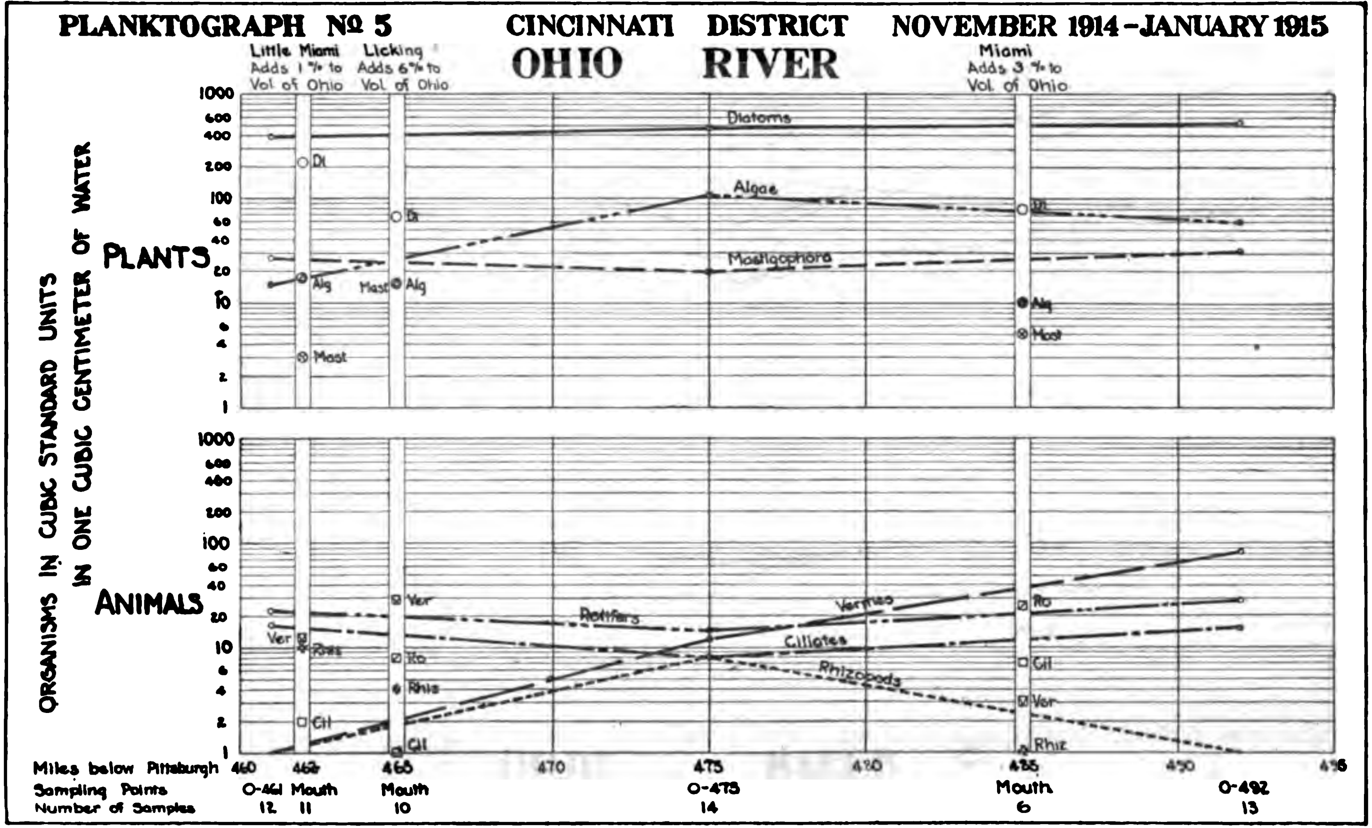


PLANKTOGRAPH Nº 3 PORTSMOUTH DISTRICT AUG.–OCT. 1914



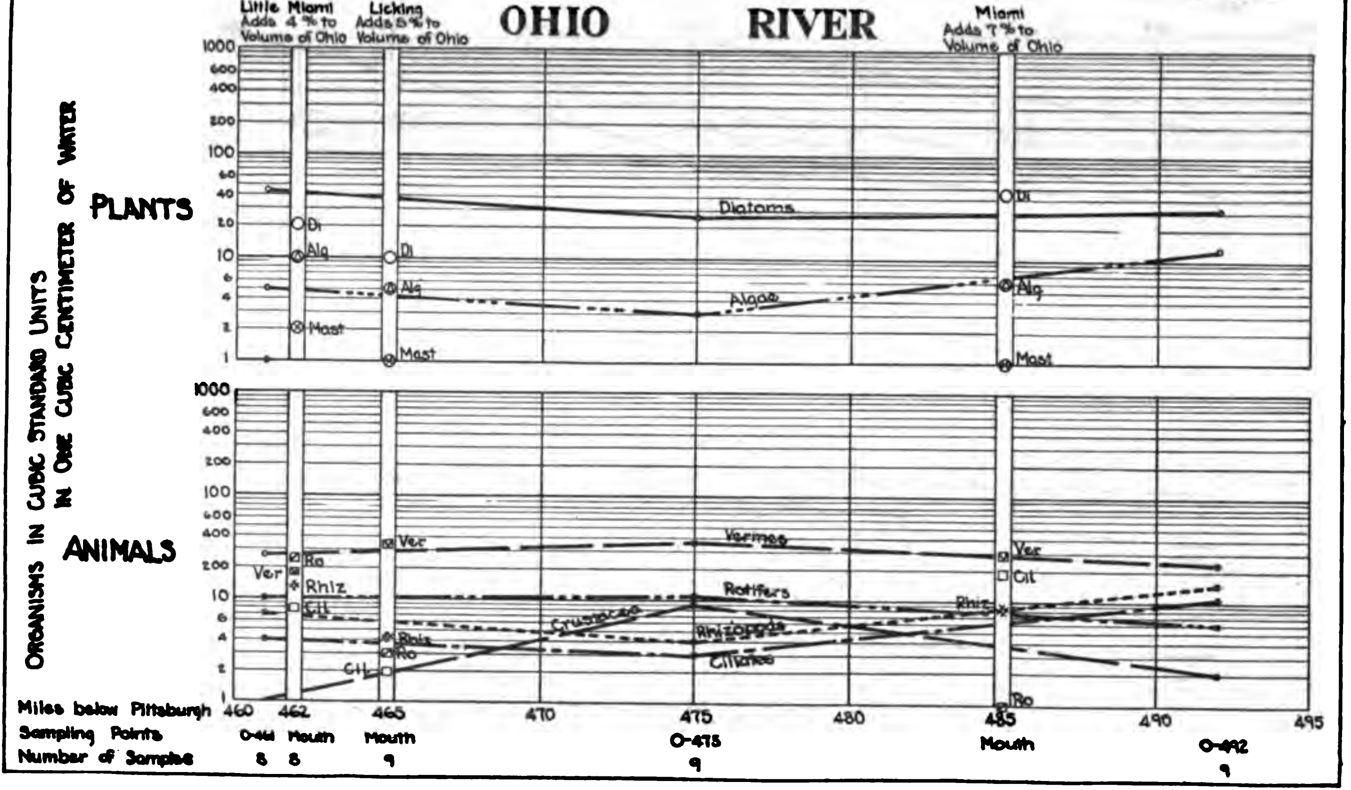

PLANKTOGRAPH № 4
CINCINNATI DISTRICT
AUGUST – OCTOBER 1914
OHIO RIVER
Little Miami Adds 3% to Vol. of Ohio
Licking Adds 3% to Vol. of Ohio
Miami Adds 12% to Vol. of Ohio
ORGANISMS IN CUBIC STANDARD UNITS IN ONE CUBIC CENTIMETER OF WATER
PLANTS
ANIMALS
1000
600
400
200
100
60
40
20
10
6
4
2
1
Alg
Di
Mast
Algae
Diatoms
Mastigophora
Ro
Rhiz
Cil
Ver
Crus
Rotifera
Ciliates
Vermes
Crustacea
Rhizopods
Miles below Pittsburgh
Sampling Point
Number of Samples
460
465
470
475
480
485
490
495
O-461
Mouth
Mouth
O-475
Mouth
O-492
8
6
6
10
8
6

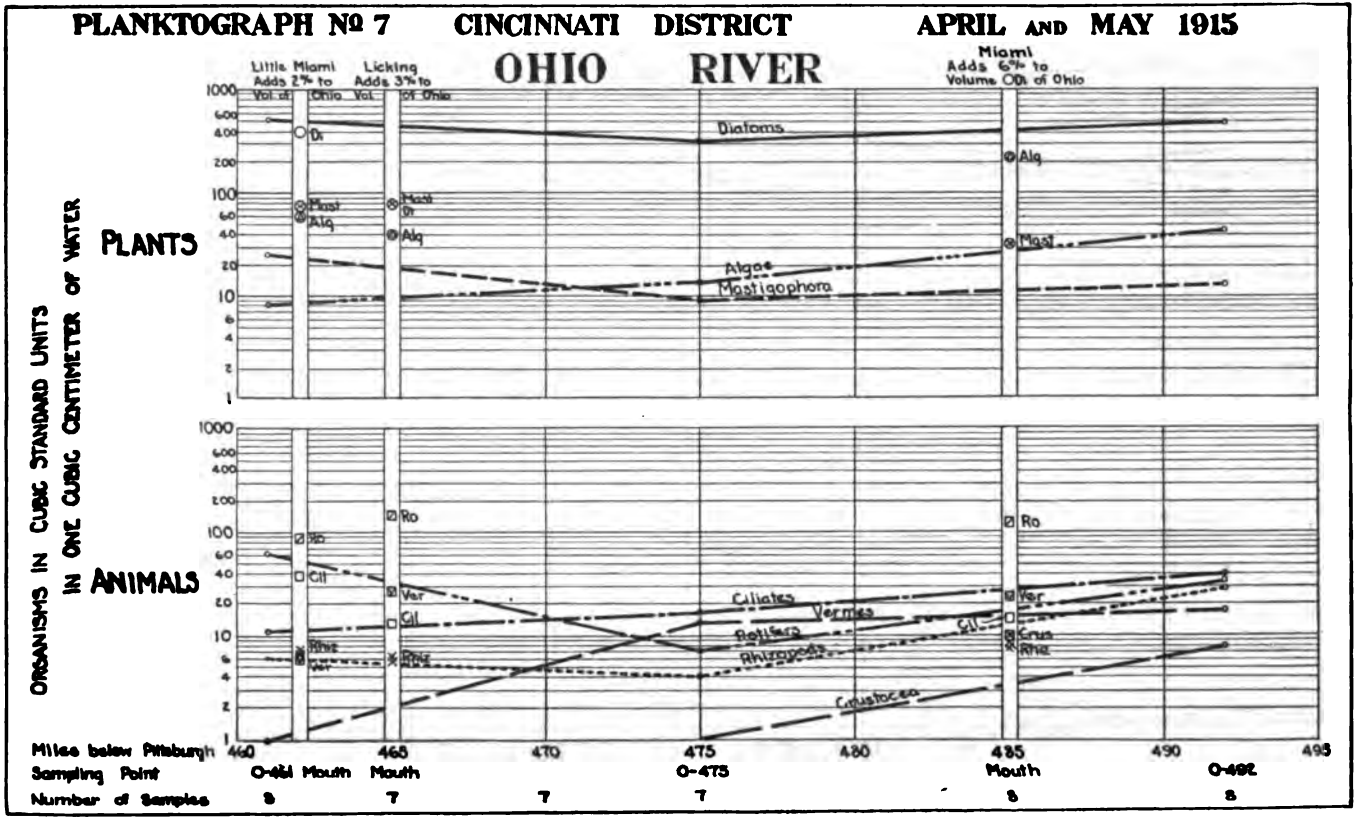


PLANKTOGRAPH No 5 CINCINNATI DISTRICT NOVEMBER 1914-JANUARY 1915

OHIO RIVER

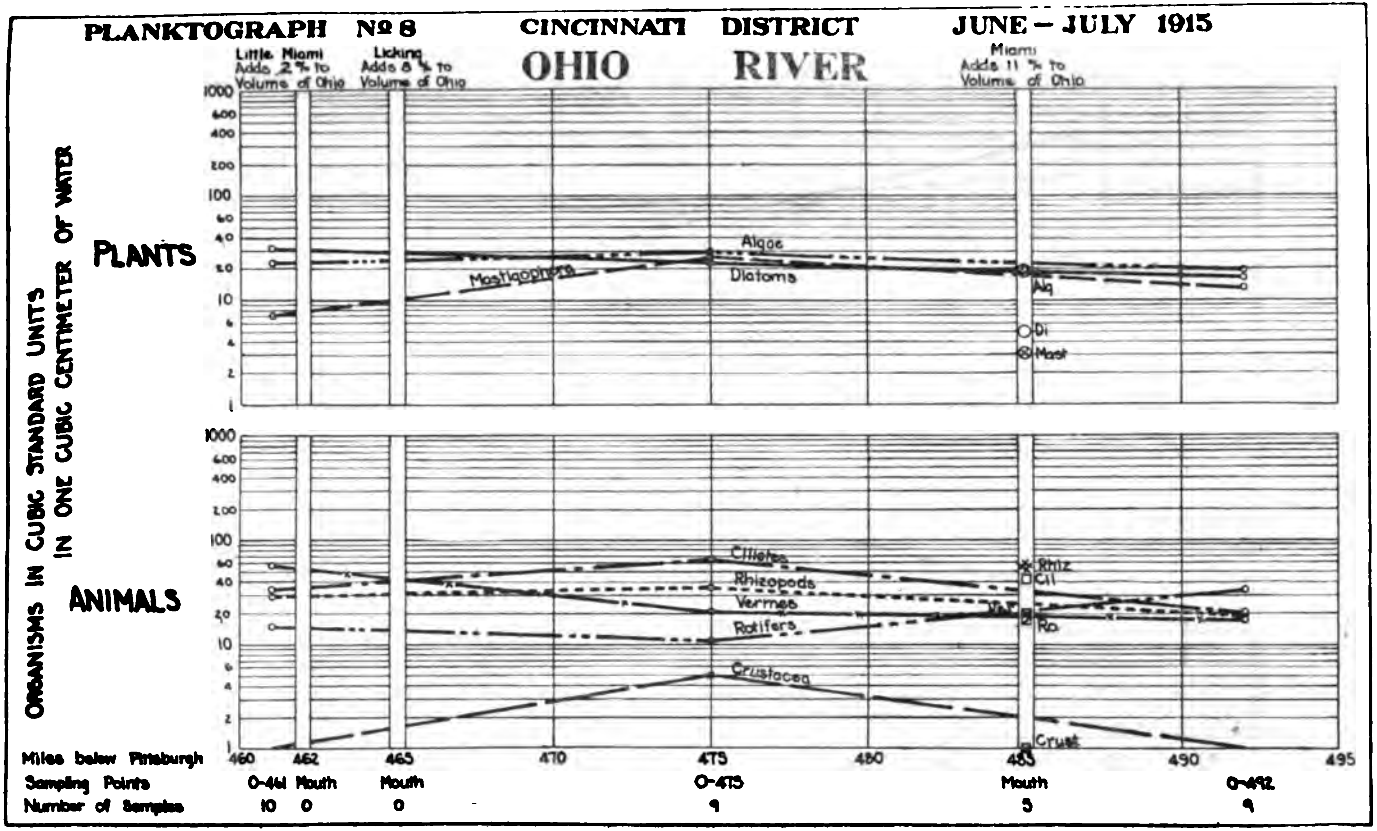
PLANKTOGRAPH Nº 6 CINCINNATI DISTRICT FEBRUARY – MARCH 1915





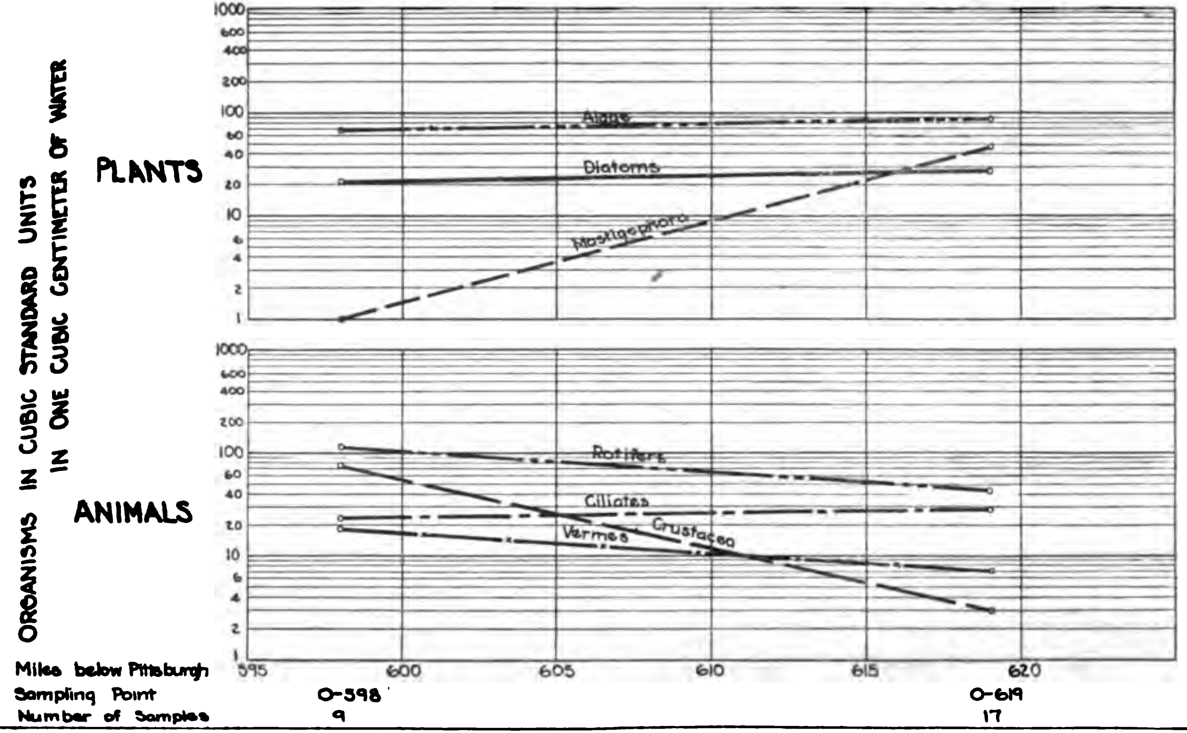
PLANKTOGRAPH No 7 CINCINNATI DISTRICT APRIL AND MAY 1915

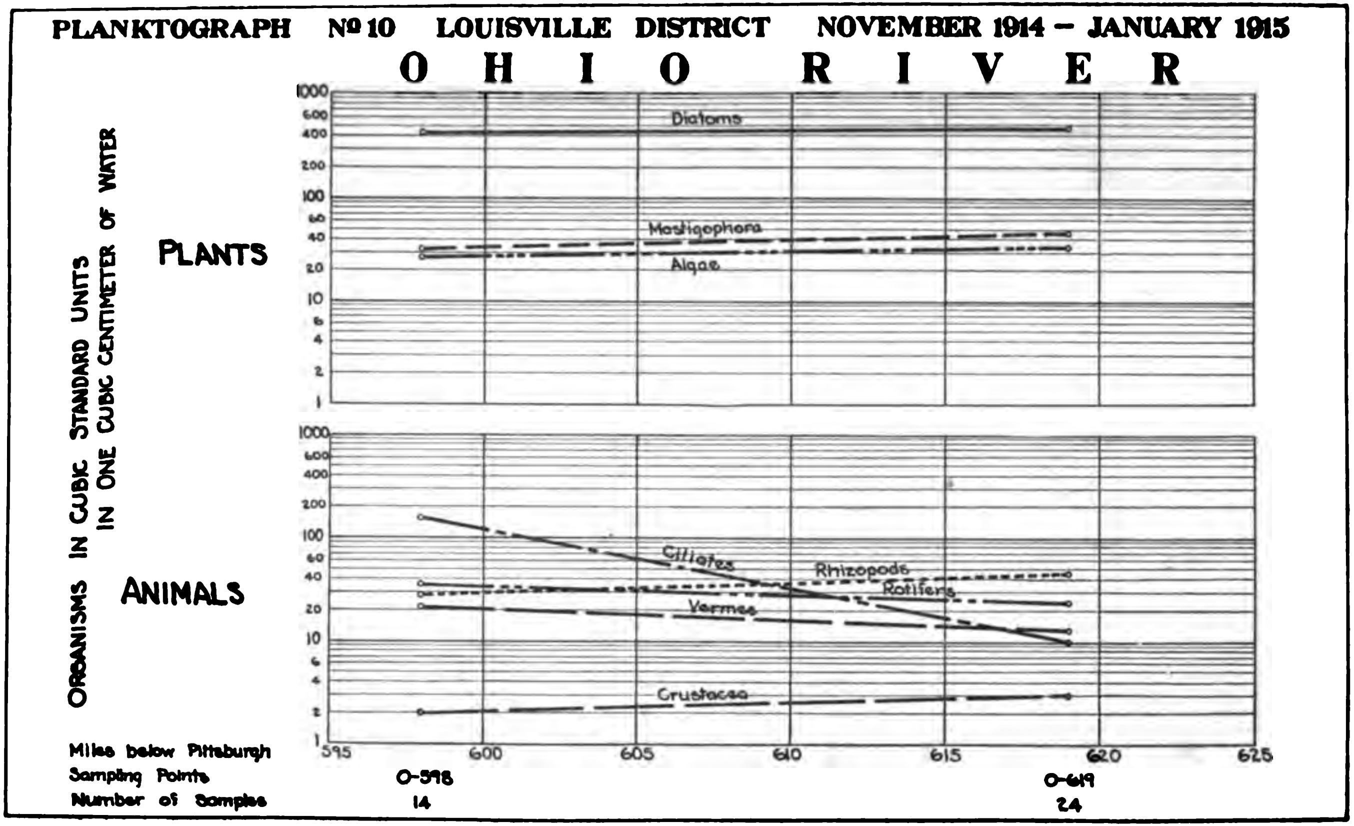
OHIO RIVER


PLANKTOGRAPH No 8
CINCINNATI DISTRICT
JUNE – JULY 1915
OHIO RIVER
Little Miami Adds .2 % to Volume of Ohio
Licking Adds 8 % to Volume of Ohio
Miami Adds 11 % to Volume of Ohio
ORGANISMS IN CUBIC STANDARD UNITS IN ONE CUBIC CENTIMETER OF WATER
PLANTS
ANIMALS
1000
600
400
200
100
60
40
20
10
6
4
2
1
Algae
Diatoms
Mastigophora
Alg
Di
Mast
Ciliates
Rhizopods
Vermes
Rotifers
Crustacea
Rhiz
Cil
Ro
Crust
Miles below Pittsburgh
Sampling Points
Number of Samples
460
462
465
470
475
480
485
490
495
0-461
Mouth
Mouth
0-475
Mouth
0-492
10
0
0
9
5
9

PLANKTOGRAPH № 9 LOUISVILLE DISTRICT SEPTEMBER—OCTOBER 1914

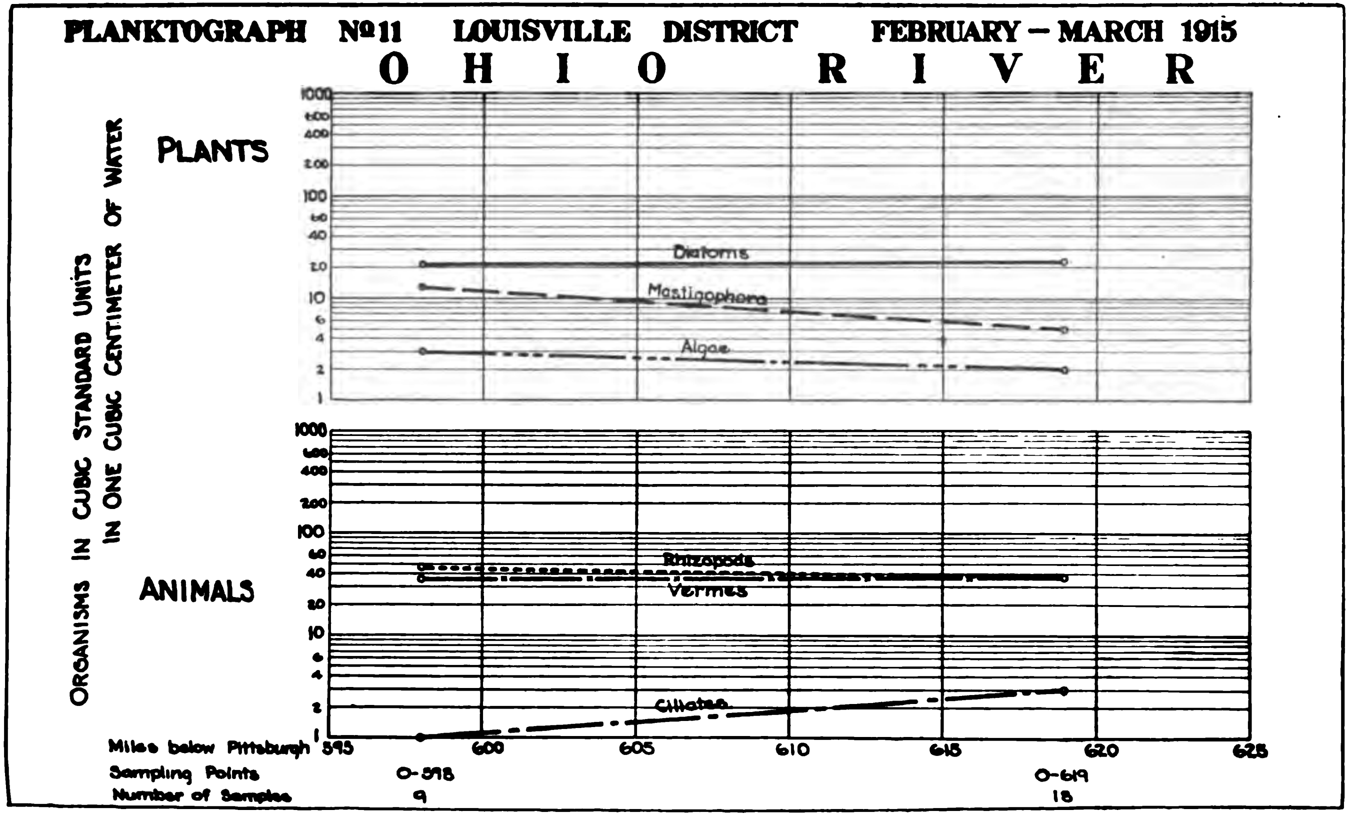
O H I O R I V E R





PLANKTOGRAPH Nº 10 LOUISVILLE DISTRICT NOVEMBER 1914 – JANUARY 1915

OHIO RIVER

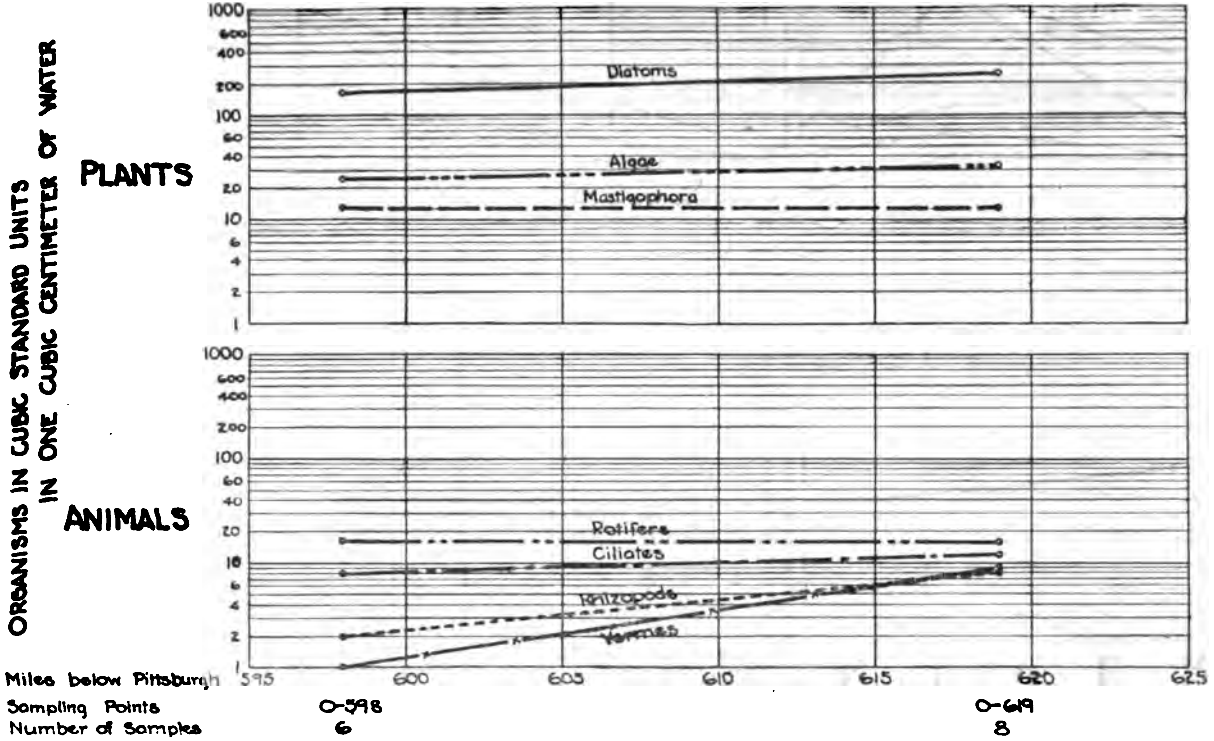


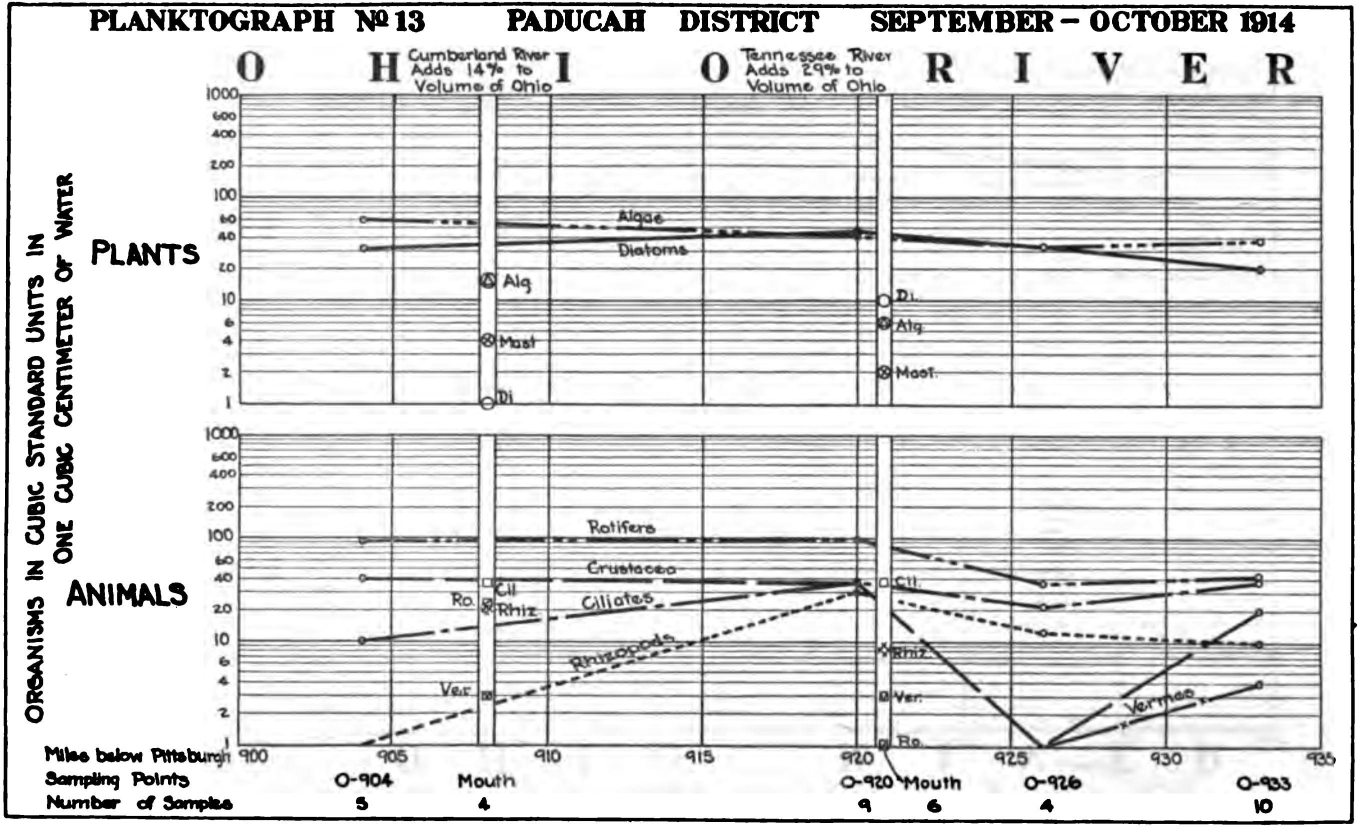
PLANKTOGRAPH No 11 LOUISVILLE DISTRICT FEBRUARY – MARCH 1915

OHIO RIVER

PLANKTOGRAPH No 12 LOUISVILLE DISTRICT APRIL – MAY 1915

O H I O R I V E R





PLANKTOGRAPH No 13 PADUCAH DISTRICT SEPTEMBER – OCTOBER 1914

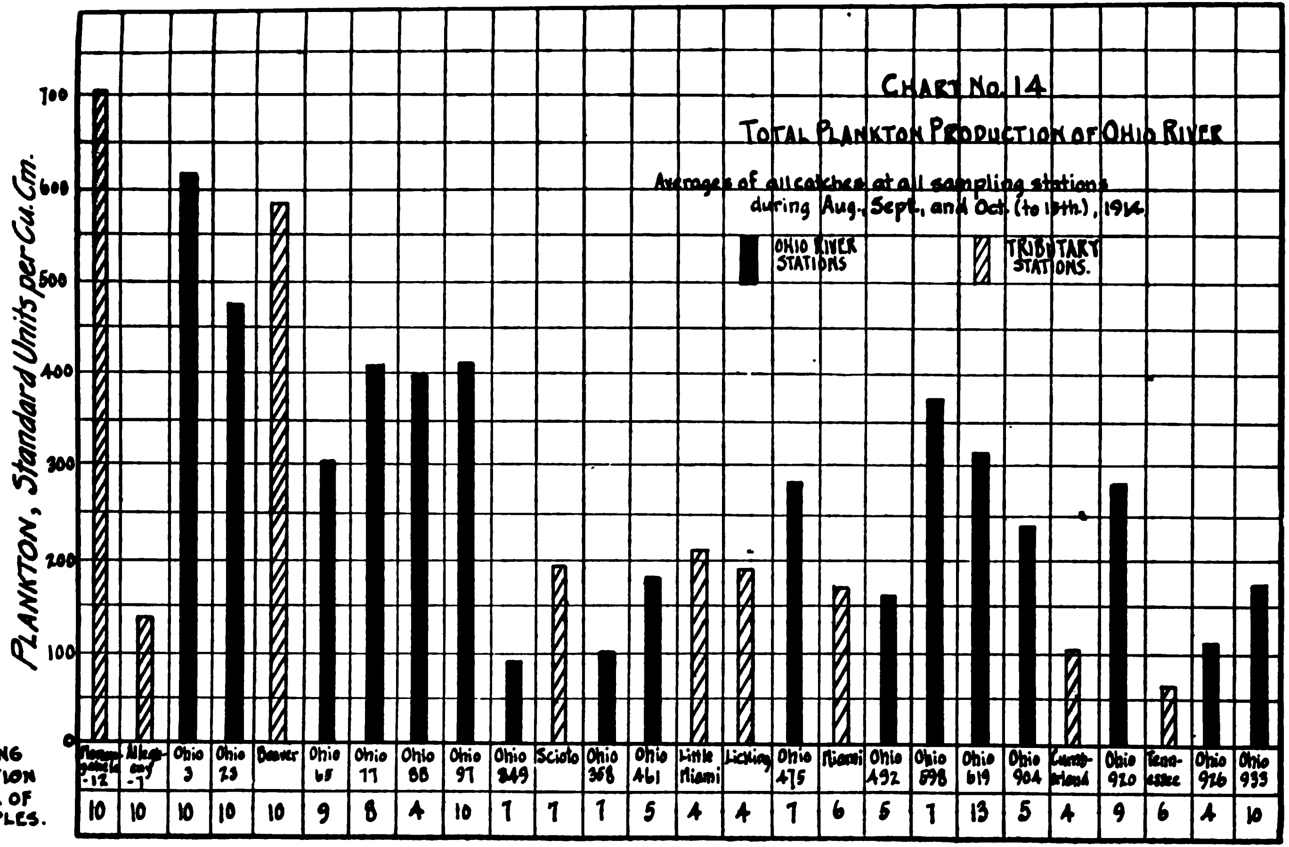


CHART No. 14

TOTAL PLANKTON PRODUCTION OF OHIO RIVER

Averages of all catches at all sampling stations during Aug., Sept., and Oct. (to 15th.), 1914.

CHART NO. 15 — SEASONAL DISTRIBUTION OF PLANKTON AT STATION 461 — Monthly Averages, July, 1914 - July, 1915.

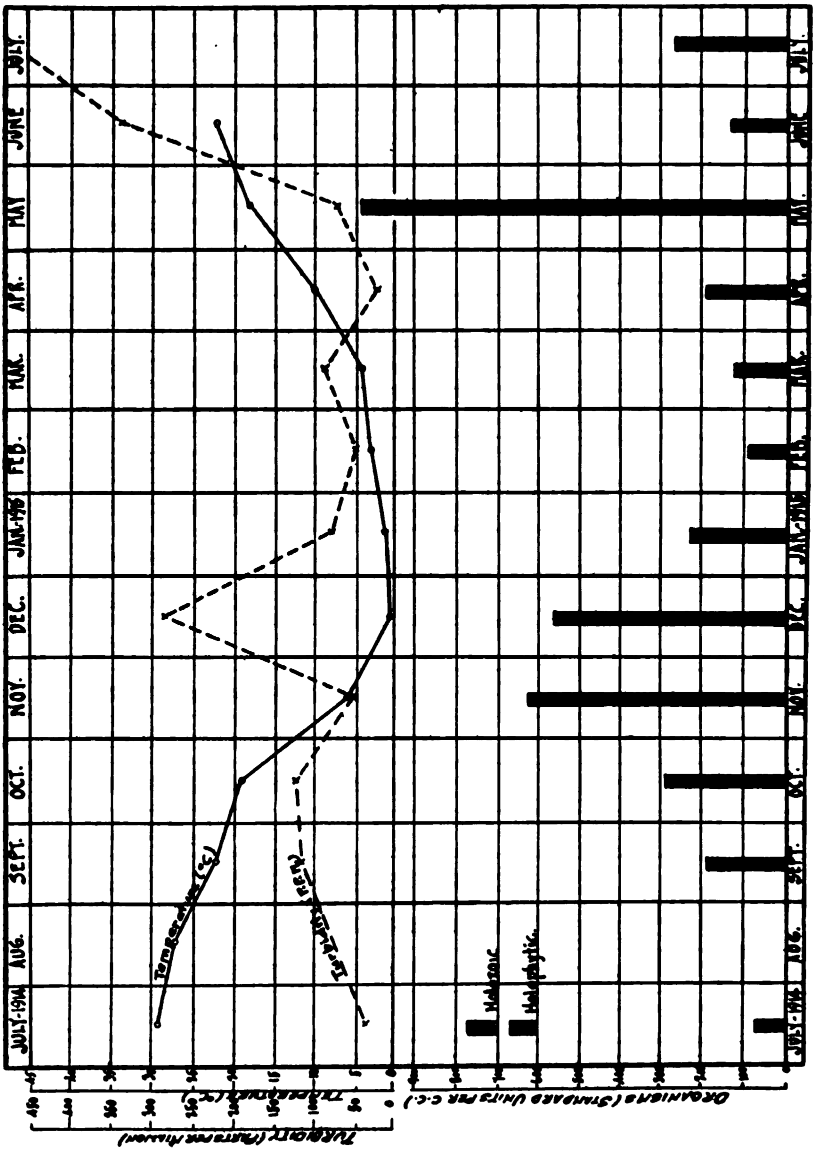


CHART NO. 16 – SEASONAL DISTRIBUTION OF PLANKTON AT STATION 475 – Monthly Averages, Aug., 1914 – July, 1915.

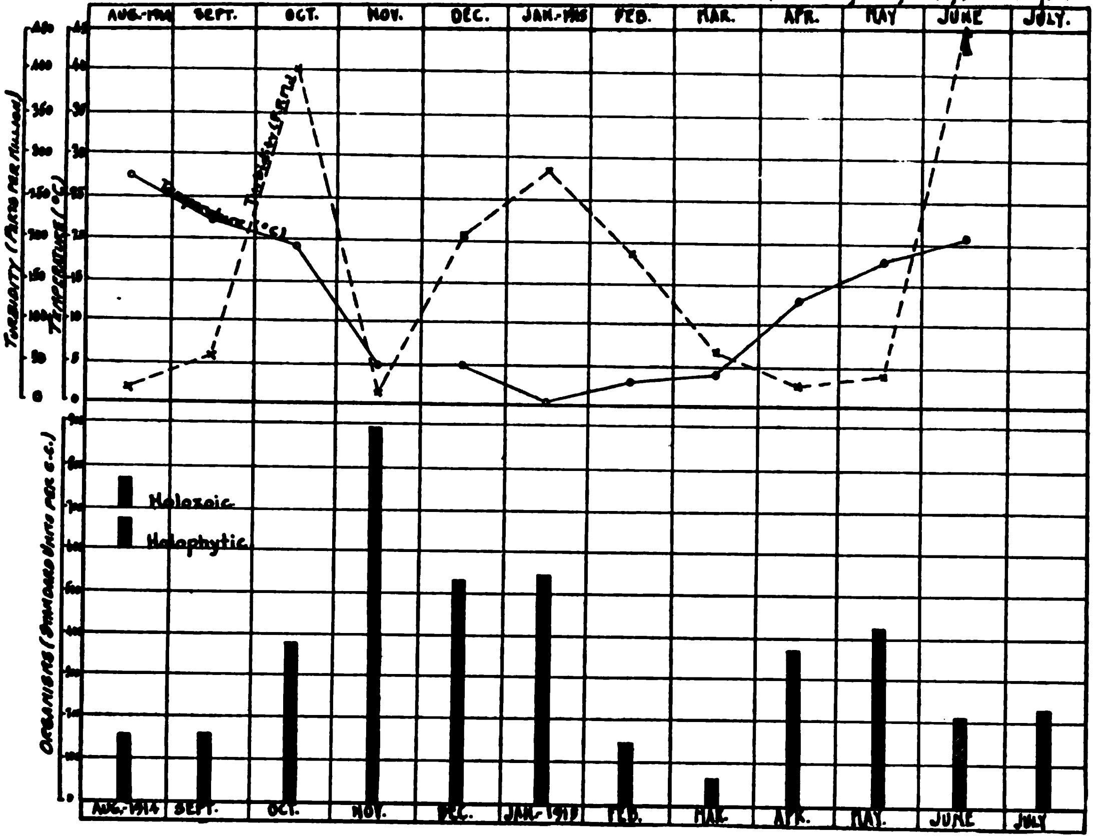


CHART NO. 17

HYDROGRAPHIC CURVES SHOWING SEASONAL FLUCTUATIONS IN DISCHARGE, THOUSAND SECOND FEET, OF LITTLE MIAMI AT PLAINVILLE, O., LICKING AT FALMOUTH, KY., AND OHIO AT CINCINNATI

PERIOD FROM JULY, 1914 TO DECEMBER, 1915.

PERIOD I: UNUSUALLY STABLE FLOW.
PERIOD II: UNUSUALLY UNSTABLE FLOW.
PERIOD III: NORMAL FLOW

Note: Vertical discharge scale for Little Miami and Licking amplified to ten times corresponding scale for Ohio

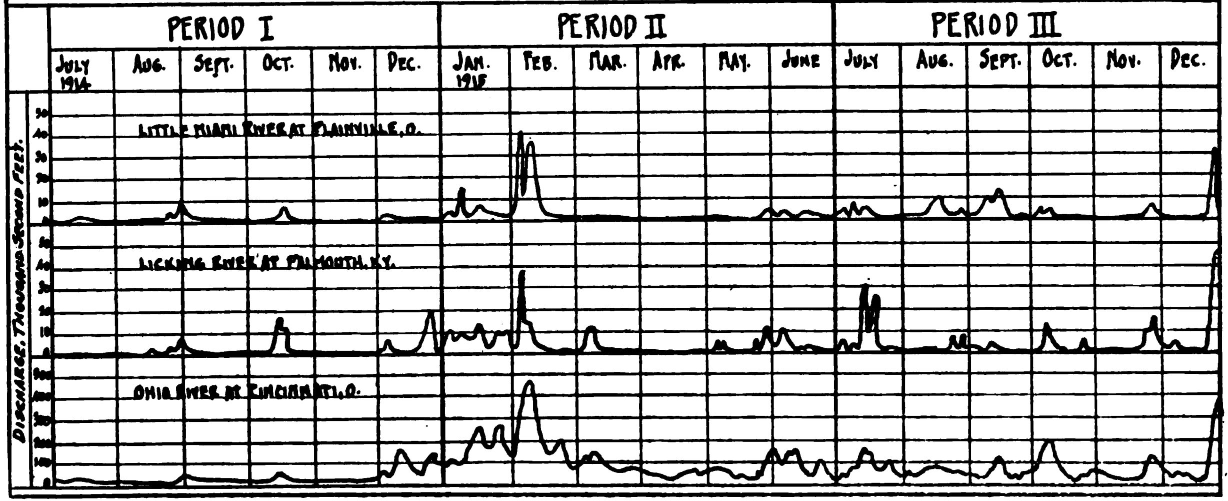
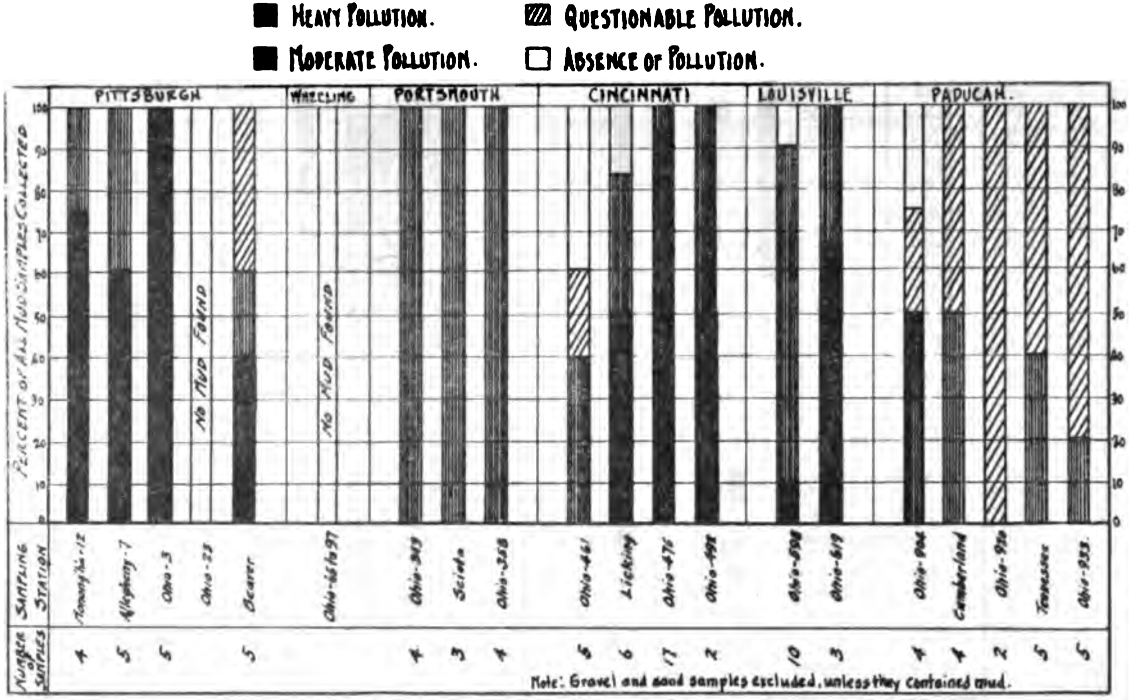


CHART NO. 18

SANITARY STATUS OF OHIO RIVER AS SHOWN BY THE PHYSICAL CONDITION AND THE ORGANISMS OF BOTTOM DEPOSITS.

COLLECTED AUG. 1 TO OCT 15, 1914



Note: Gravel and sand samples excluded, unless they contained mud.

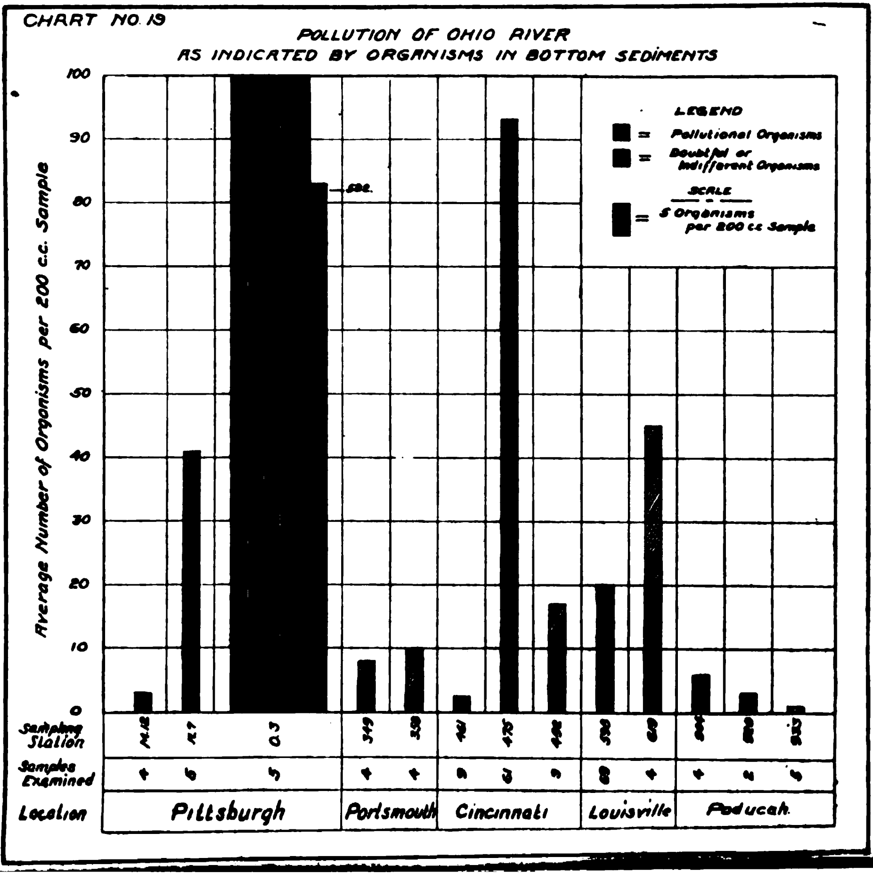


CHART NO. 19
POLLUTION OF OHIO RIVER
AS INDICATED BY ORGANISMS IN BOTTOM SEDIMENTS
Average Number of Organisms per 200 c.c. Sample
100
90
80
70
60
50
40
30
20
10
0
586.
LEGEND
= Pollutional Organisms
= Doubtful or Indifferent Organisms
SCALE
= 5 Organisms per 200 c.c. Sample
Sampling Station
M.12
R.7
0.3
349
358
461
475
492
590
619
906
920
935
Samples Examined
4
6
5
4
4
6
19
6
69
4
4
2
5
Location
Pittsburgh
Portsmouth
Cincinnati
Louisville
Paducah

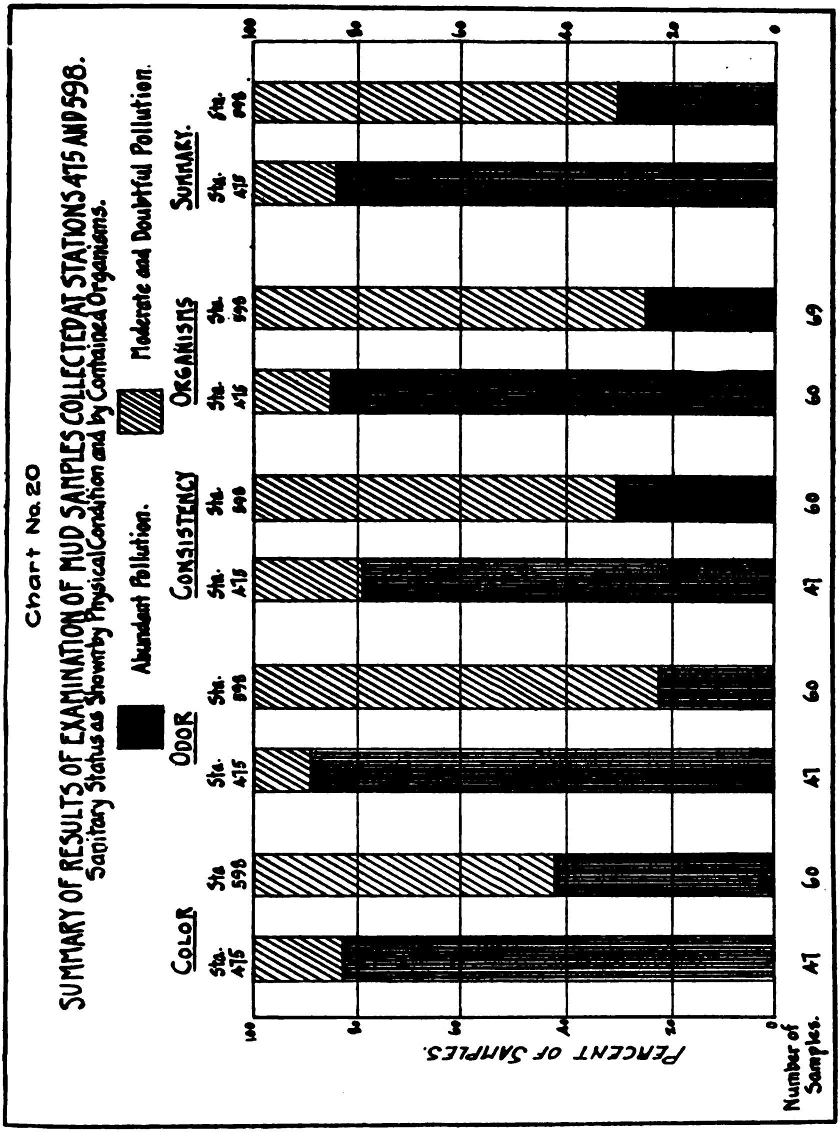


Chart No. 20

SUMMARY OF RESULTS OF EXAMINATION OF MUD SAMPLES COLLECTED AT STATIONS 475 AND 598.
Sanitary Status as Shown by Physical Condition and by Contained Organisms.

RELATED PUBLICATIONS.

Available reprints and bulletins on stream pollution, issued by the Public Health Service, from which copies may be obtained without cost:

PUBLIC HEALTH BULLETIN.

No. 74. Investigation of the pollution of tidal waters of Maryland and Virginia, with special reference to shellfish-bearing areas. By Hugh S. Cumming. 1916.

No. 86. Investigation of the pollution of certain tidal waters of New Jersey, New York, and Delaware, with special reference to bathing beaches and shellfish-bearing areas. By Hugh S. Cumming. 1917.

No. 87. Stream pollution. A digest of judicial decisions and a compilation of legislation relating to the subject. By Stanley D. Montgomery and Earle B. Phelps. 1917.

No. 97. Studies on the treatment and disposal of industrial wastes: I. The treatment and disposal of strawboard waste, by Harry B. Hommon. II. The determination of biochemical oxygen demand of industrial wastes and sewage, by Emory J. Theriault and Harry B. Hommon. 1918.

No. 100. Studies on the treatment and disposal of industrial wastes: III. The purification of tannery wastes, by Harry B. Hommon. (Final report.) 1919.

HYGIENIC LABORATORY BULLETIN.

No. 104. Investigation of the pollution and sanitary conditions of the Potomac watershed, with special reference to self-purification and the sanitary condition of shellfish in the lower Potomac River. By Hugh S. Cumming. Plankton studies by W. C. Purdy and hydrographic studies by Homer P. Ritter. 1916.

REPRINTS FROM PUBLIC HEALTH REPORTS.

No. 214. Studies on the self-purification of streams. By Earle B. Phelps. August 14, 1914.

No. 362. The sewage pollution of streams. By W. H. Frost. September 15, 1916.

No. 384. Control of pollution of streams. The International Joint Commission and the pollution of boundary waters. By Earle B. Phelps. January 26, 1917.

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TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 132
Revised April, 1924

SEWAGE TREATMENT IN THE UNITED STATES

REPORT ON THE STUDY OF FIFTEEN REPRESENTATIVE SEWAGE TREATMENT PLANTS

BY

H. H. WAGENHALS, E. J. THERIAULT
and H. B. HOMMON

PREPARED BY DIRECTION OF THE SURGEON GENERAL

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RT ON THE STUDY OF FIFTEEN REPRESENTATIVE SEWAGE-TREATMENT PLANTS

H. H. WAGENHALS,[1] E. J. THERIAULT,[2] AND H. B. HOMMON[3]

INTRODUCTION

artificial treatment of sewage is a relatively new branch of ry science developed chiefly within the last 30 years. Appreci- changes at frequent intervals, not only in the vogue of the s methods available, but also in the views of sanitarians ling the fundamental principles, purposes, and requirements vage treatment, are indications that the science is still in a stage of evolution.

original tendency, following the first full appreciation of the f sewage in the dissemination of disease, was to demand of e treatment an effluent of safe potability. With a realization difficulties and expense involved in the production of a "safe" e effluent, sentiment has gradually changed, and the present ncy appears to be toward less rigid requirements, more reliance placed upon the judicious selection of sources and the artificial cation of waters for the protection of public supplies.

horitative opinion is still somewhat at variance as to the require- in sewage treatment, but it is generally conceded that a sewage- nent plant may be rightly expected to prevent gross nuisance times, to protect water-purification plants using the receiving of water from undue loading, and, in general, to maintain the course in such a condition that its use for industrial purposes impaired. In certain cases a sewage-treatment plant may be ted to prevent the dangerous pollution of bathing beaches yster beds which, in the nature of things, can not be safe- ed by other protective methods.

in the development of any science, a number of new devices rocesses have been brought forward with enthusiastic claims their economy and efficiency. As a rule, actual performance iled to substantiate the claims originally made, although quent developments, in some instances, have restored once ded methods to good standing.

s unsettled status of sewage treatment, due largely to a lack ct data concerning the relative efficiency of different installa- the frequent failure of plants to achieve promised results, he rapid advances made in water purification, have all tended

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to promote a spirit of uncertainty and even skepticism rega sewage treatment. While this attitude is not common a those technically informed, it has nevertheless found expre among some recognized authorities and is prevalent among p officials upon whom devolves the responsibility for the constru and operation of sewage-treatment plants.

The present study was undertaken in the summer of 1920 direction of the Surgeon General, the chief purpose in view the collection of first-hand, uniform, and comparable data upo efficiency of representative plants in actual routine operation.

In planning the investigation it was realized that relatively of the plants in the country could be visited. The personnel ava for the work was limited, and it was desired to confine the limits to warm weather, which is the critical time in the oper of any sewage-treatment plant. The plants included in the s were therefore selected as representing accepted processes or binations of processes or because of special features on which i mation was desired.

It would be very easy to cast a cloud over every known m of treatment by reporting on plants which have failed becau faulty design or neglect of operation. As the primary purposes work was to secure accurate data on the efficiency of devices processes of treatment, it was necessary to select plants of comp design and receiving a reasonable amount of care and control. plants given below are considered to be representative of variou vices and processes for the most part properly designed and operated.

Special features of plants studied.

Alliance	Contact beds, glass covered sludge beds, int tent fine filters.
Canton	Contact beds, glass covered sludge beds, c trated sewage.
Atlanta	Imhoff tank and trickling filters under southe ditions.
Fitchburg	Imhoff tank and trickling filters under no conditions.
Lexington	Imhoff tank and trickling filters, compara new installation.
Columbus	Imhoff tank and trickling filters, one of the United States plants.
Rochester (Brighton)	Imhoff tank and trickling filters, small plan dilute sewage.
Baltimore	Hydrolytic tanks and trickling filters, largest States plant, fine screens.
Reading	Septic tank and trickling filters, one of the United States plants, fine screens.
Rochester (Irondequoit)	Riensch-Wurl screens with Imhoff tanks.
Houston	Activated sludge, largest plants in routine ope

San Marcos	Activated sludge, small plant with presedimentation and dilute sewage.
Sherman	Activated sludge, small plant treating a strong sewage.

The studies made at the above plants were divided into two parts. The plants were first visited by an engineer who made a physical survey of each plant. This phase of the work was completed between May 24 and September 1, 1920, an average of four days being devoted to each plant. Engineering features of design and operation were entered into and, in addition, information was obtained concerning the population served by the various plants, the total flow of sewage, the cost of construction and operation, and other basic data of importance in estimating the efficiency and economy of the plants. The devices and processes studied included grit-chambers; Riensch-Wurl and other types of screens; plain sedimentation, septic, hydrolytic, and Imhoff tanks; contact, trickling, or intermittent filters; secondary sedimentation; sludge digestion tanks; sludge beds; and activated sludge.

Attention was also given to the study of some special subjects. In particular, wherever it was found that sludge was being used as a fertilizer or soil builder every effort was made to secure first-hand information as to the results obtained. Plant operators interested in this method of ultimate sludge disposal were urged to undertake studies productive of quantitative data upon which a true estimate of the value of sewage sludges as fertilizers or soil builders might be based.

The basis of the engineering survey was a questionnaire, a copy of which may be found in Appendix II. When it was possible to secure complete sets of plans of the plants, much of the questionnaire could be filled out by reference to the plans and the details worked out at a later date in the office. It was necessary, however, to go over all details of the plants in the field at places where the original plans had been modified prior to construction.

Laboratory studies, constituting the second part of the survey, extended from May 27 to December 1, 1920, an average of 16 days being spent at each plant to secure a series of about 12 analyses. The chemist carried with him a complete equipment of the necessary laboratory apparatus and chemical reagents and worked in the local laboratories. Acknowledgment is due to the authorities in charge of the various laboratories for the facilities placed at the chemist's disposal and for the generous loan of sample collectors in several instances. At plants where the personnel was not adequate to take on the extra work, special sample collectors were employed by the Public Health Service. At some of the smaller plants practically all of the operating data, such as flow readings, etc., were collected in this manner.

The laboratory work was rather elaborate, more so than woul advisable for routine plant procedure. Some determination admittedly low value were included in order to determine wh they furnished additional information sufficient to justify the and time involved in making them. Considerable importan placed on the fact that the same methods of analysis were us all plants; in fact, at all but four plants the work was done by same chemist and at these four plants the work was intrusted to who had received special training in the methods used. It is beli that the analytical results are unique in this respect.

It was hoped that there might result from these studies a b understanding as to the efficiency of sewage treatment processes that some progress might be made toward a more or less uni schedule of methods for making analyses and reporting re Some of the plants visited are in charge of men who are recogniz the most capable plant operators in the country. From them only engineering facts were sought, but also opinions and the regarding their own plants and treatment methods in general. survey also offered a splendid opportunity for the interchang methods and ideas concerning sewage analysis. From these info discussions it appears to be quite generally the case that sev plant operators, because of insufficient funds and personnel seldom in a position to undertake the original research work w is essential for the proper future development of sewage treatm

The material embodied in this report is intended to cover the accumulated during the survey and the conclusions drawn fr study of the data. The first three chapters of the report are dev to a general discussion of the status of sewage analysis, the sam technic followed, the interpretative value of the determina made, and the conclusions drawn as to the best methods of proc available. A detailed description of the analytical methods is g in Appendix III. The engineering data and the chemical ana are presented in Chapter IV, each plant being considered separa The structural features and efficiencies of the various devices processes are summarized in Chapter V. Detailed descriptio the plants studied are to be found in Appendix I. During the p ration of the report the descriptions and discussions referrin individual plants have been submitted to the officials in charg each plant for correction and criticism. By this procedure believed that many inaccuracies have been eliminated.

In addition to the authors, Mr. M. J. Blew assisted in these st from July to September, doing laboratory work.

The success of a survey of this nature depends primarily upo cooperation of the officials from whom the basic data must b tained. It is desired to express appreciation of the assistance

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e technical press has been freely used and much material ob-
d from it as well as from the standard books on sewage treat-
. Every effort has been made to credit in the body of the report
uthors of articles from which material has been taken.

CHAPTER I

ANALYTICAL METHODS

GENERAL CONSIDERATIONS

It was realized at the start and amply confirmed during the s that any comparison of the efficiency of the various metho sewage treatment based on published analyses to be found in a reports or in the technical press would be entirely misleading. comparisons of the performance of some of the larger plants published data are, in fact, virtually impossible due to a lack o formity in the choice of the analyses made or in the methods o cedure where similar tests are conducted. Too frequently the minations are chosen with regard to local precedents or are c out in the light of individual preferences.

Once a routine has been established a strong disinclination t standardization involving radical changes is quite excusable some plants the routine analyses cover a period of years dating the time the plant was first put into operation. Any chan methods of analysis would render comparisons impossible withi plant itself, a disadvantage which must be weighed agains advantages of a modified procedure which would permit compa with results obtained in other places.

The general acceptance of the standard methods of the Ame Public Health Association has been a long step forward in the s ardization of laboratory procedures, although considerable differ are possible even in laboratories by which "Standard Methods fully adopted. Nitrates, for example, may be determined by one c methods, the reduction method or the phenol-disulphonic acid me the biochemical oxygen demand may be determined by three diff methods, viz, the relative stability method, the nitrate method the excess oxygen method; ammonia nitrogen may be detern by distillation or by direct nesslerization. It is by no means e lished that these different methods give equivalent results. I case of oxygen demand tests, even if the results obtained by the eral methods available were concordant, there would still be con able latitude in the choice of incubation temperatures or even i choice of a period of incubation. The greatest difficulty arises, ever, not in the details of the procedures themselves but in the c of the tests to be made. At one plant nitrification may be tak an index of the efficiency of a trickling filter; another plant w ar installation may consider that the permanganate oxygen umed or the relative stability is the best index.

certain sections where sewage-treatment plants are under comt State supervision the analyses to be made are specified. rtunately no agreement exists between the officials of different s as to what constitute suitable laboratory procedures. The mination of the various forms of nitrogen, for example, may be sed by some and discarded altogether by others.

the absence, therefore, of a generally accepted procedure, it is rent that in any study of sewage treatment having for its purpose comparison of the various methods in use in widely scattered ons of the country, the collection of analytical data derived r uniform conditions would be a primary requisite. No special is made for originality, or unusual refinements in the analyses itted in this report. Their chief virtue lies in the fact that they possible a direct comparison of the various plants visited, out qualification as to differences of procedure.

CHAPTER II

SAMPLING TECHNIC

NUMBER OF SAMPLES COLLECTED

The number of samples to be collected was a question w
received considerable attention. It was decided that the sam
period should cover at least 10 days if the results obtained
to be relied upon as being properly representative. Actually,
lower limit was exceeded in most cases.

METHOD OF SAMPLING

The method followed was to collect hourly samples of 150
over a full 24-hour period. These samples were composited, g
a volume of 3,600 c. c. for analysis. Sample collectors were instru
to dip below the surface of the sewage and to include all suspe
matter caught in the sample. Glass-stoppered, wide-mou
bottles provided with wire handles were used for the samp
When completely filled the stoppers were set in place, thereby g
a constant volume at each sampling period. One-gallon bo
were used for storing the composited samples.

Due to limitations of time and personnel it was necessary to co
Sunday samples. In the table given below one Sunday sa
from each place is compared with the six samples immedi
following or preceding it.

TABLE No. 1.—*A comparison of analyses of Sunday and week-day raw se*

[The values given are corresponding sums from 14 plants. Original results in terms p. p. m. and c
liter for settleable solids]

	Sus-pended matter	Settle-able solids	Oxygen con-sumed	Alka-linity	Ether soluble matter	Chlor-ides	Oxygen demand 5-day	s o
Sundays only	2,098	32.2	538	3,006	631	1,159	1,338	
Week days only	2,663	38.7	611	3,026	832	1,281	1,691	
Week days and Sundays	2,542	37.9	610	3,023	803	1,264	1,529	

The suspended matter in the Sunday samples is about 20
cent lower than in the samples collected on week days only.
cepting the dissolved oxygen, the same holds true for the c
determinations. The values derived from a consideration of w
day results only are not materially different from those in w
a Sunday sample was included. The inference is that the omis

nples for a 24-hour period each week would not materially the weekly average. Possibly the omission of two or three lays would still give a perfectly reliable average value.

er methods of sampling practiced at various places are as s:

Sampling according to flow is practiced at Fitchburg, Mass., s, logically, the correct procedure; the use of direct-reading neasuring devices is implied.

s method has the advantage that the analytical results are ted. Sampling errors, however, are largely counterbalancing constant volume samples are taken. This is brought out in llowing table prepared from data contained in the report on at the sewage-testing station at Cleveland, 1914. The values are monthly averages.

No. 2.—*Agreement between samples proportioned to flow and those where a constant amount of sample was taken at each sampling period*

[Results in parts per million]

ples	Month	Oxygen consumed	Suspended matter			Organic nitrogen	Free ammonia	Chlorine	Alkalinity	Iron (Fe)
			Total	Volatile	Fixed					
	April	45	195	88	107	7.2	12	286	155	14
	do	47	204	98	106	7.3	13	284	157	15
	May	50	252	114	138					
	do	52	269	116	153					

A, samples proportioned to flow. B, a constant volume of sample taken.

A single sample is taken at a time of the day found by experi- to represent the average strength of the sewage. This method owed at Baltimore. It has the advantage that sample collec- re practically eliminated, but it can be used only where the sition of the sewage is nearly constant.

PRESERVATION OF SAMPLES

attempt was made to preserve the samples other than by ration. The hourly samples were transferred as soon as pos- fter collection to a 1-gallon stoppered bottle kept on ice or in box. Excepting the dissolved oxygen content, the changes take place in the composition of an iced sample within 24 are probably not very great.

some plants chloroform is used as a preservative; acids are sed for the same purpose. If biochemical oxygen demand or cibility tests are to be made, sterilization, evidently, is not ssible. In interpreting the results of analyses it should be in mind that bacterial activity is only slowed down and not etely arrested by refrigeration. Chloroform alone is of doubt- lue as a preservative; acidification is effective. Chloroform and ration together are also effective.

COMPETENCE OF THE SAMPLES

It is believed that the results obtained are fairly represen of average summer conditions at the plants visited; in fact, wit exception of Atlanta where heavy rains were encountered, the r for any given plant vary but little from day to day. Sudden ations are generally connected with the unloading of a tank heavy rain. At all plants, with possibly one or two exceptio was agreed by the local officials that the analyses were fairly r sentative, and, wherever the methods in use by the local che were at all comparable, the results were found to agree quite cl

The following table gives data collected from various sourc establish this point of agreement:

TABLE No. 3.—*Agreement between the values obtained by local chemists an obtained during the survey*

[Results in parts per million]

Plant	Suspended matter				Source from which local values were c
	Raw sewage		Final effluent		
	Local value	Survey value	Local value	Survey value	
Alliance	158	152	16	17	Average from May to October, 1919, f nual report.
Atlanta (Intrench)	140	106			From paper read at twenty-third annu vention of Am. Soc. Mun. Imp., b Hommon.
Atlanta (Peachtree)	145	226			Do.
Baltimore	185	159	40	41	Average from April to October, 1912 from Eng. News-Record of July 21,
Columbus	219	206	78	81	Average from May to October, 1920, f nual report.
Fitchburg	346	297	35	42	Average from May to October, 1919, f nual report.
Lexington	203	166	34	48	Average of 3 analyses from May to Ju
Rochester (Brighton)	121	101	12	10	Average from April to October, 1918, f nual report.
Reading	104	145	30	31	Do.
Sum	1,621	1,558	245	270	
Average	180	173	27	30	

In the above table the suspended-matter determinations during the survey are compared with values derived by local c ists. The agreement in the case of the final effluents is very and even with raw sewage a good general agreement is obta Unfortunately it was found impossible to extend this table, sinc suspended-matter determination is about the only test in ge use on which practical agreement obtains as to the metho procedure.

CHAPTER III

PRETATIVE VALUE OF THE VARIOUS DETERMINATIONS MADE DURING THE SURVEY

rative, laboratory, and administrative work at sewage plants
rally in excess of the available personnel. The selection of
e laboratory tests and the elimination of timeworn or tedious
inations of doubtful value should receive the careful attention
plant operator.

laboratory schedule followed during the survey is given below.
ıded most of the tests that are commonly made on sewage,
ble exception being the total nitrogen. This determination
not very well be included due to the bulky nature of the
tus required. The resulting list is a cumbersome one, and
capable of furnishing comparative data of great value is obvi-
not recommended for routine procedure.

inity.
ides.
gen as nitrate.
ive stability.
able solids.
nded matter.
7. Ammonia nitrogen.
8. Ether soluble matter (fats).
9. Oxygen consumed.
10. Dissolved oxygen.
11. Biochemical oxygen demand.
12. Complete sludge analysis.

he following pages the interrelation of the above determina-
nd their limitations when applied to sewage analysis will be
discussed. The importance of the biochemical oxygen
d test will be emphasized by frequent reference to this value.
nalytical results presented to illustrate the text are taken
ables given in Chapter IV, and detailed descriptions of the
ical methods used are given in an appendix to this report.

1. ALKALINITY

a raw sewage this value is determined largely by the alkalinity
water supply, the presence of industrial wastes, and, especially,
indicator chosen for the test. No particular significance is
ed to the alkalinity of the raw sewage excepting, of course,
industrial wastes are present in unusual quantities. More
ant are the changes in the value of the alkalinity as the
passes through a plant.

TABLE NO. 4.—*Changes in the alkalinity of a sewage on passing through septic, or hydrolytic tanks*

[Results in parts per million]

Source	Alliance	Atlanta (Intrench)	Atlanta (Peachtree)	Baltimore	Canton	Columbus	Fitchburg	Lexington	Rochester (Irondequoit)	Roch este (Brig ton)
Effluent	194	82	69	144	343	219	99	194	190	18
Influent	184	77	68	136	342	211	97	196	175	17
Increase	10	5	1	8	1	8	2	−2	15	1

Excepting at Lexington, where a slight decrease was not plants indicate an increase in alkalinity, although the increas small that it can be ascribed, largely if not entirely, to experi errors. At places like Alliance, Reading, and Rochester, increases of 10 to 15 parts per million were noted, the chang possibly be connected with a slight unloading of material fro sludge chamber where, as shown in the following table, the a ity reaches a very high figure.

TABLE NO. 5.—*Comparison of the alkalinity of Imhoff sludge filtrates with the corresponding raw sewage*

[Results in parts per million]

Source	Alliance	Atlanta (Peachtree)	Baltimore	Columbus	Fitchburg	Lexington	Rochester (Brighton)
Sludge filtrate	880	520	380	890	980	1,150	640
Raw sewage	184	68	138	211	97	196	178
Increase	696	452	242	679	883	954	462

The alkalinity of the filtrate from freshly drawn sludg determined at most plants visited. The results are summari the above table and compared with the alkalinity of the corresp raw sewage.

It is noted that the differences shown in Table No. 5 are too to be attributed to experimental errors. The maximum in was at Lexington and is in the neighborhood of 1,000 part million. From the analyses of the sludge ash, as given l Table No. 63, it can be calculated that the $CaCO_3$ content wet sludges varies from 2,000 to over 5,000 parts per million. of this $CaCO_3$ is, of course, not in solution, but it is not inconce that the sludge filtrate contains as much as 1,000 parts per n especially when consideration is given to the fact that the deco tion of the sludge gives rise to large amounts of carbon di Also it must be remembered that the sludge represents, roug least, that part of the sewage which is in coarse suspension tleable matter, and that the inorganic matter content of this i is presumably higher than that of the liquid part of the . The conditions are, therefore, favorable for the concen- of inorganic salts in the sludge and for the solution of the 1 carbonate in the surrounding liquid.

foregoing discussion has been presented entirely from the oint of the classical methods of analysis and interpretation, thout reference to the limitations of the titrimetric method determination of alkalinity. That this simple treatment is neans satisfactory is fully recognized.

end-point reached with an indicator, such as methyl orange presence of weak organic acids, which can be assumed to be t in sludge filtrates, is by no means definite. The color changes ed are very gradual, and the tendency is to add too much The end-point is also rendered uncertain by the presence of substances, such as phosphates and proteins, which act as , tending to oppose any sharp change in the color of the or. Under these conditions end-points are indeterminate ossibly meaningless. Instead of representing $CaCO_3$, the ity results may merely be a measure of how well the sludge is buffered. Unfortunately, data on the hydrogen ion tration of sludge filtrates are not available and some practical ties will have to be solved before such determinations can be

decrease in the alkalinity of a sewage on passing through a g filter, a contact bed, or an activated sludge plant is shown following table. The nitrates and the 5-day oxygen demand effluents are also included for comparison.

No. 6.—*Changes in the alkalinity of a sewage on passing through an oxidizing device*

[Results in parts per million]

Source	Trickling filters								Contact beds		Activated sludge			
	Fitchburg	Baltimore	Reading	Rochester (Brighton)	Lexington	Atlanta (Intrench)	Atlanta (Peachtree)	Columbus	Alliance	Canton	Houston (south side)	Houston (north side)	San Marcos	Sherman
:														
nt	99	144	177	189	194	82	69	219	194	343	304	270	311	515
nt	8	63	105	131	152	48	35	192	167	354	220	198	239	416
ease	91	81	72	58	42	34	34	27	27	−11	84	72	72	−1
s nitrates	5.2	3.3	4.4	2.8	.....	3.0	2.0	0.6	2.8	0.3	6.0	4.6	8.8	1.2
en demand	20	14	20	7.1	16	4.2	8.9	49	20	37	7.4	11	16	40

Whatever significance may be attached to alkalinity results
changes shown above are not subject to the same sources of er
in the case of the determinations made on sludge filtrates. I
sludge filtrates the presence of weak organic acids and of b
might account for a good part of the indicated change in alkal
but in the effluent of an oxidizing device the organic matter co
has been greatly reduced and the end-points reached are very sh
defined. The significance of these results is emphasized by comp
the decrease in alkalinity with the degree of nitrification an
oxygen demand of the effluents at plants where the raw sewag
somewhat comparable. At Fitchburg, where a maximum decre
91 parts per million was observed, a maximum of nitrification
trickling filter effluent, 5.2 parts per million of nitrogen as nit
and a low oxygen demand were also found. At Columbus,
the raw sewage is somewhat comparable to that of Fitchbur
smallest decrease in alkalinity, 27 parts per million, was accomp
by the lowest nitrification, 0.6 parts per million, and the hi
oxygen demand, 49 parts per million, observed in any filter effl
It might be objected that at Fitchburg the filtering mater
composed of trap rock, while at Columbus limestone, which
have an effect on the alkalinity, is used. The same general ten
is noted, however, if Lexington be substituted for Fitchburg.
nitrate figures are not available for Lexington, the oxygen de
results are 49 and 16, and the decrease in alkalinity 27 an
respectively, for Columbus and Lexington.

The same result is noted if the results from two contact be
compared. Alliance shows a decrease in alkalinity of 27 part
million and Canton shows a slight increase or practically no ch
the effluent at Alliance is much more stable than that at Cant

It does not appear that this relation between alkalinity ch
and oxidation is limited to devices involving the use of a solid
material. Large decreases in alkalinity were found at the Ho
and San Marcos activated sludge plants, and these plants pr
very highly stabilized effluents. At Sherman a condition of
tically no change in the alkalinity of the sewage in passing th
the plant is correlated with an effluent of much poorer quality.

The Brighton plant at Rochester gave an effluent of very
quality and showed much smaller decrease in alkalinity tha
Fitchburg or Baltimore plants, but the raw sewage at Brighton
much weaker than the raw sewages at Baltimore and Fitchbur
a comparison of these plants is not justified.

If the values given in Table No. 6 are considered along with
criteria on which the efficiency of a plant may be estimated, it ap
that a sizable reduction in the alkalinity of the sewage as it p
through an oxidizing device is correlated with the efficient beh

plant or, roughly, that the reduction in alkalinity is a measure biological activity within the oxidizing device.

s conclusion, admittedly, would rest on a somewhat firmer basis ead of the reduction in alkalinity, we were to consider the dis- ent in the pH value of the sewage due to its passage through dizing device. Data on this displacement in the pH value are ailable except, by inference, at Fitchburg, where the pH value ich that the effluent of the trickling filters was practically l to methyl orange. The indicated pH value in this case is in ighborhood of 4.0. The pH value of raw sewage is in the orhood of 8.0. If instead of methyl orange an indicator, such hyl red, with a color change occurring above a pH value of 5, en chosen the Fitchburg effluent would have reacted acid, and luent alkaline.

he absence of more complete analytical data it would be haz- to present any definite conclusions. It would seem probable, er, that the displacement in the pH value of the sewage on g through an oxidizing device, might be a measure of the amount logical activity that has been expended on the purification of wage, or otherwise stated, a measure of the amount of organic r that has been worked over by the bacteria. It would be ed that, other things being equal, the greatest displacement l occur where the amount of organic matter oxidized was the st.

m the tables presented above and the accompanying discussion pparent that the alkalinity of a sewage is subject to decided es as the sewage passes through a treatment plant. These es, however, are not readily interpretable due to the uncertain cance of the alkalinity determination. It would seem that the tution of the readily applied colorimetric determination of the gen ion concentration for the old titrimetric alkalinity deter- ion would furnish information of more definite character and t potential value in the operation of a sewage-treatment plant. this determination requires no greater time or skill, and does volve the use of more expensive apparatus than that required e titrimetric determination of alkalinity, it seems advisable to e the alkalinity determination by the determination of the gen ion concentration. This has already been done by the iologists in the preparation of their culture media, where it has hown that it is the hydrogen ion concentration of a medium than its alkalinity which determines, largely, its suitability for owth of bacteria. If bacterial activity can be favored by an ment of the pH value of a medium, it would seem that a study age purification from this angle of approach would offer a most ing field of investigation.

It would be highly desirable, for instance, to secure data pH value of well-digested sludges with the object of deter whether such values can not be used to indicate the fitness of for withdrawal from a tank.

The foaming of Imhoff tanks is another phenomenon app correlated with a change in the character of biological activi which no satisfactory explanation or method of control is available. Here again a knowledge of the hydrogen ion conc tion involved might offer a mode of attack. The slight incr the alkalinity of a tank effluent is possibly paralleled by a change in the hydrogen ion concentration, and might give va information as to the behavior of the Imhoff tank.

The decided decrease in the alkalinity of a sewage on through an oxidizing device is undoubtedly connected with a in the hydrogen ion equilibrium. Here, too, hydrogen ion de nations might give a measure of the biological activity.

At plants where acid wastes are encountered, adjustment sewage to a normal pH value, say 8.0, would seem to be rational method than an adjustment to a given alkalinity. wise, in experiments on sludge digestion, the adjustment of the to a pH value most favorable to the special types of bacteria in would seem a logical method of procedure. Certainly in exper on the chemical precipitation of sewage the pH value is an imp factor, especially if it is considered that, for many substanc optimum pH value exists above or below which precipitat imperfect.

2. CHLORIDES

The chloride content of a strictly domestic sewage shoul somewhat with the concentration of the polluting material an the character and amount of the industrial waste contrib Since the chloride content does not change in passing throu plant, the determination is of potential value only in estimati strength of a raw sewage. Its usefulness for this purpose is limited, however, and, on the whole, it can be safely stated th determination does not give data of sufficient value to warr inclusion in a routine schedule of analyses.

In Table No. 7, the chloride results obtained during the have been arranged in the descending order of their magnitud the corresponding 5-day oxygen demand results have been below.

To. 7.—*Comparison of the chloride content of raw sewage with its 5-day oxygen demand*

[Results in parts per million]

ination	Houston (north side)	Sherman	Reading	Columbus	Houston (south side)	Atlanta (Intrench.)	Lexington	Atlanta (Peachtree)	Baltimore	San Marcos	Rochester (Irondequoit)	Canton	Fitchburg	Alliance	Rochester (Brighton)
	136	129	120	113	101	93	89	86	86	83	82	79	70	47	45
n demand	115	202	118	190	112	63	144	52	120	67	104	213	155	92	67
	0.9	1.6	1.0	1.7	1.1	0.7	1.6	0.6	1.4	0.8	1.3	2.7	2.2	2.0	1.5

agreement between the chloride content and the oxygen l would be indicated by a rather constant value for the ratio wo. By inspection it is apparent that the relation is a very ne. In the above table, the chloride results are uncorrected chloride content of the water supply, and at some places an able error would perhaps be introduced by this omission. As however, the chloride content of a water supply is low comvith sewage. At Houston, Atlanta, and Rochester, where nts were studied, the chloride content appears to vary someirectly with the oxygen demand. Without corrections for oride contribution of the industrial wastes, the strength of a as indicated by its chloride content would be entirely mis-

able No. 8 the contribution of chlorine as chloride at the visited has been computed in terms of grams per capita per The plants are arranged in the ascending order of this quantity.

To. 8.—*Contribution of chlorine as chlorides in grams per capita per day*

	Canton	Sherman	Rochester (Brighton)	Alliance	Fitchburg	San Marcos	Houston (south side)	Lexington	Baltimore	Houston (north side)	Columbus	Rochester (Irondequoit)	Reading	Atlanta (Peachtree)	Atlanta (Intrench.)	Average value
	79	129	45	47	70	83	101	89	86	136	113	82	120	86	93	----
capita per	64	44	128	131	88	80	75	89	106	75	94	137	101	160	167	----
capita per	19	21	22	23	23	25	29	30	35	39	40	43	46	52	59	34

able No. 8, the chloride content of the water supply has been ed; the chlorine determinations are those made during the survey; and the total flows are average flows under dry w conditions.

The average contribution at the plants studied was 34 gra capita per day with an average deviation of about ±10. grams this value.

If the per capita per day contribution of chlorine as chlori taken as 34 grams and the chloride content of the sewage is k the gallons of sewage per capita per day can be computed. probable error involved in such a computation, however, wou very great.

3. NITROGEN AS NITRATES

Nitrification is a time-honored and widely used criterion quality of an effluent. For the determination of nitrates in s effluents it is necessary to use the reduction method, since, i presence of chlorides in amounts above 10 or 15 parts per m the phenol-disulphonic acid method is entirely unreliable. reduction method, while capable of giving accurate results, is consuming and, in many respects, unwieldly. It is to be bor mind that the quantity reported as nitrates by this method in the nitrites, unless the nitrite content has been determined on a rate sample and deducted. The inclusion of the nitrites, how introduces no serious error, since the nitrite content is usually low and the significance of the two forms of nitrogen is muc same. The term, "reducible nitrogen," is probably more descr of the value in question.

While the degree of nitrification can be taken as a good in judging the efficiency of a particular plant, it is not a value whic be used for a comparison of various methods of treatment estimating the relative efficiency of different plants, unless assumed that the nitrogen content of all sewages is the sam assumption which is surely not warranted.

Other things being equal, the amount of nitrates present effluent should be somewhat proportional to the amount of able material present. If it is assumed that the nitrogen cont sewage is roughly proportional to its strength or to the concent of polluting material in the sewage, it would appear that a sewage, although very highly purified, could not be expected to as high a nitrate content as a much stronger sewage whic reached an equally high degree of purification. This appears the condition at some of the plants visited. For example, i nitrate content of 6.1 parts per million in the final effluent fro Fitchburg plant is compared with the nitrate content of onl parts per million in the final effluent from the Rochester pla might be inferred, using the extent of nitrification as a basis of parison, that the Fitchburg plant was operating much more efficiently than the Rochester plant. The raw sewage at Fitchburg, however, is more than twice as strong as that at Rochester and, if the above reasoning is correct, the nitrate content at Fitchburg should be twice as high as at the Rochester plant. These two plants have been chosen for comparison because it is believed that each one is turning out about as good an effluent as is possible with the methods of treatment used.

In the interpretation of nitrate results, therefore, the strength of the raw sewage should be considered, and allowance made for the fact that nitrification, measured in absolute units, is not a suitable test for use in comparing the relative efficiency of various plants unless complete information concerning the various forms of nitrogen is available. It is very doubtful whether the additional information gained would justify the time and labor involved.

4. Relative Stability

A decided advantage of this method is its simplicity, which makes it available for use by a nontechnical plant foreman in judging the quality of an effluent. In general, if an undiluted effluent holds up for five days at ordinary temperatures, it can be stated that the effluent is sufficiently stabilized and will not cause gross nuisance.

During the survey relative stability tests were made with tests for the biochemical oxygen demand by the excess oxygen method. The results obtained by the two methods are fairly concordant, due allowances being made for the limitations of the relative stability test. The time required for the decolorization of methylene blue is not a quantity that can be determined very accurately, since the color change involved is by no means always sharply defined. Unmistakable colorations will persist for days after the bulk of the color has disappeared, and this can hardly be ascribed to reaeration when the color is uniformly distributed throughout a tightly stoppered bottle. Whatever the explanation may be, the frequent absence of a sharp end-point affects the accuracy of the relative stability method somewhat seriously, and makes it inadvisable to use the relative stability determination where more than roughly quantitative information is desired. The degree of concordance between the two methods will be illustrated by a few examples.

At the Houston north side plant the effluent samples incubated in the presence of methylene blue held up for 10 days or over and the 5-day oxygen demand of the effluent was 11 parts per million; at Fitchburg the samples held up for 10 days also, but the oxygen demand was 21. At the Rochester Brighton plant the samples held up for over 5 days and the oxygen demand of the effluent was 5.2 parts per million, while at Lexington the relative stability samples held up for over 5 days also, but the oxygen demand of th ent was 16 parts per million. At Canton, Sherman, and Colu however, the samples incubated in the presence of methylen held up for less than 5 days and the oxygen demand values w 40, and 49, respectively.

From the above illustrations, and from tests made at other it appears that whenever the 5-day oxygen demand is below 20 per million the relative stability test will show that the effluer all about alike, i. e., the samples will not decolorize within 5 days. If the oxygen demand is in the neighborhood of 40 parts per million, this fact will be indicated by the decolorizat methylene blue after less than 5 days of incubation. A choi tween the two methods of estimating the quality of an efflu determined by the degree of accuracy desired, or the use to the information is to be put.

Considering the two activated sludge plants at Houston, it wo impossible to determine by inspection or by the physical appe of the effluents which plant was giving the better effluent, the eff at both of these plants being very highly purified. The stru features of these plants are almost identical, the main diff being the number of units provided. The methods of ope however, differ in some respects, e. g., at one plant sludge re from the sedimentation tank is continuous, while at the oth sludge is removed intermittently. The relative stability tes cates that both plants are performing equally well, all samples ing up for at least 10 days. The 5-day oxygen demand of the side plant, however, was 11 parts per million, while that of the side plant was only 7.4 parts per million. These results are in a ance with other chemical data from which the character of t effluents might be judged, e. g., the degree of nitrification, t solved oxygen content, and the character of the sludge.

The relative stability test can also be used for estimati strength of a raw sewage. The dilutions involved and the nec determinations of the initial available oxygen content, ho require the services of a chemist, in which case the strength sewage is best determined by the oxygen demand test with a higher degree of accuracy and, possibly, a lesser expenditure o

5. SETTLEABLE SOLIDS

The settleable solids represent the coarser portion of the susp matter or, better, that portion of the suspended matter which out readily. This quantity may be determined by noting th ume of the solids which settle out in a given time from a volume of sewage contained in a glass vessel of suitable shape. results are expressed in cubic centimeters of solids that settle a given volume of sewage within a specified time. The settleable solids may also be determined by weight if the suspended matter in the raw sewage is known and the suspended matter in the supernatant fluid of the raw sewage is determined after allowing the solids to settle for a definite time.

The following table has been prepared to bring out the relationship between these two quantities:

TABLE NO. 9.—*Comparison of the settleable solids by volume with the settleable solids by weight in raw sewage*

Settleable solids.	Sherman	Canton	Baltimore	Rochester (Brighton)	Reading	San Marcos	Columbus	Alliance	Houston (north side)	Rochester (Irondequoit)	Fitchburg	Houston (south side)
Cubic centimeters per liter	5.0	5.3	2.9	2.0	2.0	2.2	3.1	2.0	2.5	2.1	2.7	2.0
Parts per million	179	190	114	83	90	100	146	115	154	138	241	178
Ratio	36	36	39	42	45	45	47	58	62	66	89	89

The agreement between the ratios given in the above table is a rough measure of the correspondence between the settleable solids by volume and the settleable solids by weight. It is not to be expected that the agreement would be any too close, since the determination of settleable solids is subject to many sources of error. The variation in the value of the ratio is to be connected, to some extent at least, with the character of the settleable solids, and the deviation from the average ratio is a rough measure of the state of disintegration of the settleable solids. The effect of the degree of disintegration on the settleable solids by volume is well illustrated at the Rochester Irondequoit plant, where the settleable solids by volume in the raw sewage before and after passing through a Riensch-Wurl screen were 2.1 and 2.3 c. c. per liter respectively. In this case the apparent increase was very evidently due to a change in the character of the suspended matter, the settled solids in the Riensch-Wurl screen effluent being visibly more highly disaggregated than those in the raw sewage. In the case of Imhoff and septic tank effluents the settleable solids by volume, as a rule, are hardly measurable with any degree of accuracy.

In the following table a comparison is made between the settleable solids by volume and the total suspended matter in the effluent of the sedimentation tanks studied.

TABLE No. 10.—*Comparison of the settleable solids by volume with the to pended matter in tank effluents*

Solids	Rochester (Brighton)	Fitchburg	Lexington	Atlanta (Intrench)	Alliance	Atlanta (Peachtree)	Columbus	Reading	Canton	Baltimore
Settleable [1]	Tr.	Tr.	Tr.	0.6	Tr.	Tr.	Tr.	Tr.	0.3	0.
Suspended [2]	40	63	67	67	69	69	70	85	93	10

[1] Tr. indicates less than 0.1 c. c. per liter.
[2] Results in parts per million.

In general, it is only when the total suspended matter rea value of about 100 parts per million that the settleable soli greater than a trace, i. e., 0.1 c. c. per liter. The applicability settleable solids by volume determination to tank effluents is, fore, restricted to the extreme case. While it is very useful f purpose, it can not be used to differentiate a very good from effluent. With a raw sewage the test is universally appl since a measurable amount of settleable solids is always p In this case the determination can furnish information of va preliminary studies, such as are made at sewage-testing st where the volume of the settleable solids is a factor in the des a tank.

The foregoing remarks, however, are not applicable to acti sludge plants. Here the volume of the sludge is an imp factor in the control of plant operation and the determinat the volume of the settled sludge is an important test. The v occupied by the same weight of sludge is greatly influenced l settling period chosen and the character of the sludge. Sinc vated sludge has a tendency to decompose very rapidly, the s period can hardly be extended much over a half hour, and for r plant operation, where the volume of the sludge in the sys to be maintained within a favorable range, the time of settlin be even shorter. The following table illustrates the change in v with respect to time:

TABLE No. 11.—*Volume of settled activated sludge after various intervals*

Nature of sludge	Time in minutes								T
	0	2	5	10	15	30	60	Over-night	
Tank effluent	1,000	700	420	325	280	230	180	....	Imh
Returned sludge	1,000	....	950	910	890	820	720	425	
Do	1,000	990	980	970	950	900	750	380	Cyl

anding overnight the sludge from the tank effluent had risen op of the vessel while the returned sludge occupied a volume . c. in the Imhoff cone and 380 c. c. in the 1,000 c. c. cylinder. dent that the volume of the sludge changes very rapidly with e. Other tests of similar nature indicate that the volume is uenced by the shape of the vessel used. Cylindrical vessels, 1,000 c. c. graduates, appear to be the most satisfactory.

terpreting this test as applied to activated sludge it is to be mind that the volume occupied by the settled sludge does r a constant relation to the actual weight of sludge present he character of the sludge remains the same. If sludge is d of having "gone bad" its physical appearance, its odor, or are probably better indications than the volume it occupies ng. These facts are brought out in the following table:

o. 12.—*Comparison of the volume occupied by settled activated sludge from aeration tank effluents with its total suspended matter content*

Plant	Volume in c. c. per liter		Suspended matter in parts per million	Ratio 30 minutes	Ratio 15 minutes
	After 15 minutes settling	After 30 minutes settling			
"VERY GOOD" SLUDGE					
uth side)	260	240	10,500	44	44
	250	225	8,990	40	36
"GOOD" SLUDGE					
rth side)	380	300	6,750	22	18
	280	240	4,950	21	18
	250	180	4,220	23	17
	200	180	4,270	23	21
	200	160	4,020	25	20
	160	150	3,200	21	20
"FAIR" SLUDGE					
	380	300	3,640	12	9.6
	280	230	2,000	8.7	7.1
"BAD" SLUDGE					
	490	380	2,070	5.5	4.2
	500	360	1,960	5.4	3.9
	500	350	1,700	4.9	3.4
	500	380	1,540	4.1	3.0

pparent from this table that the conclusions reached at differts would differ widely if the volume of the sludge were taken dex of the amount of sludge present. At Sherman, where the volume of sludge was obtained, the actual weight of the sludge was the least. At the Houston south side plant the volume of sludge was very low but the actual weight of the sludge was the highest observed, reaching a value of around 10,000 parts per million, or about 1 per cent. If instead of comparing different plants, however, results obtained at any particular plant are examined, it appears that the volume bears a definite relation to the actual weight of sludge present. This is indicated by a fairly constant value at any given plant for the ratio of the volume after 30 minutes' settling to the actual weight of sludge in the effluent. Since the character of the sludge did not change appreciably in the short period spent at each plant, it seems logical to conclude that the volume occupied by the sludge does bear a rather definite relation to the actual weight of sludge present as long as the character of the sludge remains the same. This relation is, however, affected to a surprising extent by any change in the character of the sludge.

At the Houston south side plant, where the highest ratio, 42, was obtained, the sludge was characterized as "very good sludge" and the plant was in very good working order. At the Houston north side plant, where the average ratio was 23, some difficulty had been experienced with the sludge just previous to the survey. The sewage treated at this plant is not much stronger than at the south side plant, and the final effluent, although very highly purified, was not quite as good as that from the south side plant. At San Marcos, where the ratio is about 8, the sewage receives some preliminary treatment before reaching the activated-sludge plant, by which a good part of the suspended matter is removed. The 5-day oxygen demand of the effluent from this plant is about twice as great as that of the Houston plants, and the 5-day oxygen demand of the plant influent is only about one-half as great. This plant could not be said to be working as efficiently as the larger Houston plants. The Sherman plant wa admittedly out of order, and the sludge could very well be characte ized as "bad" sludge. The ratio derived is about 5.

From the above discussion it would appear that, for an accura estimate of the quality of activated sludge, the volume occupied b the settled sludge as well as its suspended matter content must b determined. It also appears, from the comparison of the ratios of th suspended matter to the volume, that the volumes obtained after 1 minutes of settling will give information of about the same degree reliability as if the longer period of 30 minutes had been used.

6. Suspended Matter

This test is of fundamental importance in sewage analysis both a guide in the design of a plant and as an aid to its proper operatio Using the Gooch crucible method, the determination can be ma with a relatively high degree of accuracy, the probable error varyi with the character of the suspended matter. The main source of error is due to the difficulty of securing a representative sample since, without a disproportionate expenditure of time, it is seldom possible to filter more than 50 to 100 c. c. of sewage. With a raw sewage the tendency is for the results to be too low, due to the necessary exclusion of the larger particles such as fruit skins, and other substances of similar nature which are best described as settleable solids. If these coarser particles are first removed and the balance of the sewage is well disintegrated, as by vigorous shaking, the accuracy of the test is considerably increased. This is well illustrated by the following results obtained at Rochester in a study of Riensch-Wurl screens.

TABLE No. 13.—*Variations in suspended matter determinations*

[Results in parts per million]

Date	Raw sewage				Riensch-Wurl screen effluent			
	Duplicates		Average	Per cent deviation	Duplicates		Average	Per cent deviation
	A	B			C	D		
1920								
July 24	460	296	378	21.8	312	308	310	0.6
26	250	264	257	2.7	286	280	283	1.1
27	204	190	197	3.5	202	206	204	1.0
28	138	128	133	3.8	132	136	134	1.5
29	164	122	143	14.7	144	148	146	1.4
Averages	243	200	222	±9.3	215	216	215	±1.1

All tests recorded in the above table were made on samples composited over 24-hour periods. Before removing a portion for the test, the bottles were shaken vigorously and every precaution was taken to make the analyses comparable in every way. The results tabulated under columns A and B are duplicate determinations made on the raw sewage, and the results under columns C and D are duplicate determinations made on the Riensch-Wurl screen effluent. This effluent was in every way comparable with the raw sewage excepting that the coarser particles had been removed and the rest of the suspended matter had been well disintegrated by the action of the brushes. The result was a sample with a very homogeneous suspended matter content. This is indicated by the excellent agreement between the duplicate determinations and the low average deviation, 1.1 per cent, which in this case is a measure of the probable error involved. The corresponding raw sewage samples collected and tested under exactly the same conditions show an average deviation of 9.3 per cent from the average value obtained when duplicate tests are made.

The series of tests presented is not sufficiently extensive to be made the basis of very definite conclusions. It nevertheless confirms a general opinion and shows an unmistakable tendency. A more extensive series of tests presented in Table No. 41 indicates that the suspended matter content increased by about 5 per cent on passing through the Riensch-Wurl screen. This obviously questionable result is readily explained if it is considered that the results for the suspended matter content of the raw sewage may be in error by over 9 per cent and that the tendency is for the raw sewage results to be too low. The amount of suspended matter removed by the Riensch-Wurl screen would have to be in the neighborhood of 10 or 15 per cent before any removal could be indicated with certainty by suspended matter determinations. A direct weighing of the screenings removed is, of course, the indicated method of procedure. The limitations of the suspended matter determination do not lead to serious errors of interpretation, however, when the test is applied to the effluents of the ordinary devices. Since in any complete system of sewage treatment the removal of the bulk of the suspended matter in the form of sludge is one of the main objectives, this determination is of great value and in most cases an error of 10 per cent, or even more, does not affect the validity of the conclusions drawn. The test is especially useful for the estimation of the per cent removal effected by the various types of tanks and is the best index available for judging the efficiency of tank treatment.

The suspended matter determination is also of great importance in estimating the fitness of effluents from oxidizing devices for discharge into streams, since an imperfect removal of suspended matter is probably a more frequent cause of gross nuisance than an insufficient stabilization of the soluble impurities in the sewage. For this reason the suspended matter content of the final effluent is a test which can not very well be omitted in an analysis of sewage.

7. Ammonia Nitrogen

This test was made only at the four activated sludge plants visited during the survey. In the following table the values obtained are compared with the results of two other determinations.

TABLE No. 14.—*Comparison of the ammonia nitrogen content of sewage at different stages of purification with the results of other determinations*

Plant	Raw sewage		Septic tank effluent		Final effluent		
	Ammonia nitrogen	5-day oxygen demand	Ammonia nitrogen	5-day oxygen demand	Ammonia nitrogen	5-day oxygen demand	Nitrogen as nitrates
San Marcos	15	67	17	57	2.8	16	8.8
Houston (south side)	18	112			1.7	7.4	6.0
Houston (north side)	17	115			4.3	11	4.6
Sherman	26	202			23	40	1.2

e no definite conclusions can be derived from such a small · of observations, the indications are that the ammonia a content, in general, varies directly with the oxygen demand ersely with the nitrate content, i. e., a low nitrogen content is ed with a low oxygen demand and high nitrates. On the he determination appears to be of value at activated sludge The test can very readily be performed if the direct nessler- method is used. The information furnished by the test is of ratory nature and its usefulness is limited to that extent. dering the results presented in Table No. 14, it is evident that nmonia nitrogen had been completely converted into nitrates, ate content of the final effluents from the Houston plants ave been 7.7 at the south side plant and 8.9 at the north side Even if an allowance is made for the presence of forms of a other than ammonia nitrogen, the total potential nitrates activated sludge plants would hardly exceed 10 or 12 parts ion. In this connection it is to be noted that a considerable of the total nitrogen disappears during the aeration process, bly as free nitrogen. If no nitrogen was lost, the potential tion might reach 30 or 40 parts per million.

8. ETHER-SOLUBLE MATTER (FATS)

ther-soluble matter of the raw sewage was determined at all risited. The results, summarized in Table No. 15, indicate quantity of this constituent is subject to considerable varia-

o. 15.—*Comparison of the ether-soluble matter (fat) content of raw sewage with its 5-day oxygen demand*

[Results in parts per million]

mination	Rochester (Brighton)	San Marcos	Rochester (Irondequoit)	Houston (south side)	Alliance	Houston (north side)	Baltimore	Lexington	Canton	Fitchburg	Sherman	Columbus	Atlanta (Peachtree)	Atlanta (Intrench)
e matter........	16	18	34	36	37	39	40	58	62	63	69	100	83	104
n demand.......	67	67	104	112	92	115	120	144	213	154	202	190	52	62
....	4.2	3.7	3.1	3.1	2.5	2.9	3.0	2.5	3.4	2.4	2.9	1.9	.....	.....

e above table the plants are arranged in the ascending order itude of the ether-soluble matter content of the respective excepting the Atlanta Peachtree plant. At both the Atlanta he ether-soluble matter content appears to be disproportionately high. Assuming the ether-soluble matter content of the average sewage to be about 40 parts per million, the total fat content of sewage is about 330 pounds per million gallons or one-half ounce per capita per day.

The ether-soluble matter appears to vary somewhat directly with the 5-day oxygen demand. Except at the Atlanta plants, the oxygen demand is about three times as great as the ether-soluble matter content.

This determination was also made on sewage sludges. The results are presented in Table No. 62.

9. OXYGEN CONSUMED

While this test has lost a great deal of its former importance due to the introduction of biochemical oxygen demand methods, it is, nevertheless, so generally in use that it was thought advisable to include it in the tests made during the survey. The significance of the test is best shown by a comparison with the corresponding oxygen demand values.

TABLE NO. 16.—*Comparison of permanganate oxygen consumed with 5-day biochemical oxygen demand results*

[Results in parts per million]

Plant	Analyses at various stages of operation									Percentage purification effected as judged by—	
	Raw sewage			Tank effluents			Filter or final effluents				
	Oxygen consumed	5-day oxygen demand	Ratio	Oxygen consumed	5-day oxygen demand	Ratio	Oxygen consumed	5-day oxygen demand	Ratio	Oxygen consumed	5-day oxygen demand
Rochester (Brighton)	24	67	2.8	15	36	2.4	5.9	5.2	0.9	75	92
San Marcos	29	67	2.3	18	57	3.2	8.5	16.0	1.9	71	76
Lexington	32	144	4.5	22	87	4.0	9.8	16.0	1.6	69	89
Atlanta (Intrench)	35	62	1.8	21	23	1.1	10.0	4.2	.4	71	93
Atlanta (Peachtree)	35	52	1.5	18	20	1.1	7.0	3.9	.6	80	93
Alliance	38	92	2.4	26	68	2.6	11.0	20.0	1.8	71	78
Houston (south side)	38	112	3.0				6.4	7.4	1.2	83	93
Rochester (Irondequoit)	39	104	2.7	35	74	2.1					
Baltimore	43	120	2.8	36	125	3.5	8.3	12.0	1.4	81	90
Houston (north side)	45	115	2.6				10.0	11.0	1.1	78	90
Reading	45	118	2.6	31	96	3.1	14.0	15.0	1.1	69	87
Canton	61	213	3.5	38	129	3.4	18.0	37.0	2.0	70	83
Columbus	63	190	3.0	46	134	2.9	28.0	49.0	1.8	56	74
Sherman	64	202	3.2				37.0	40.0	1.2	50	80
Fitchburg	65	154	2.4	37	95	2.6	16.0	21.0	1.3	75	86
Average			2.7			2.7			1.3	71	86

The average ratio derived for raw sewages and tank effluents is 2.7, while for relatively highly purified effluents it is only 1.3. As the raw sewage becomes more and more purified the two values, apparently, tend to approach each other. This dependence of the value included for comparison. In general, the dissolved-oxygen content is not correlated with the oxygen demand of the sample. If temperature effects, however, are eliminated by comparing plants in the same city, e. g., the Atlanta plants or the Houston plants, the dissolved oxygen content appears to vary inversely with the oxygen demand, as would be expected. For the proper interpretation of dissolved oxygen results a knowledge of the temperature conditions is essential. On the whole, it appears that the determination of the dissolved oxygen content of an effluent possesses its greatest value when used as an adjunct of the biochemical oxygen demand test.

11. Biochemical Oxygen Demand

This test was made on the raw sewages and the various effluents at all plants visited. Throughout the preceding discussion the other tests used in sewage analysis have been compared with the corresponding oxygen demand value. The test appears to furnish by far the most valuable information as to the behavior of the plants and the efficiency of the various devices used in sewage purification. With suitable precautions a high degree of accuracy is attainable, and once a routine has been established the time and labor involved is no greater than is required for a nitrate determination or an oxygen-consumed test. The oxygen demand determination has the decided advantage that it is applicable to sewage in all stages of purification, and the information that it furnishes can be used independently of the results of other determinations.

When dilutions are made with raw sewage, the degree of dilution can be used in estimating its effect on a receiving body of water. In the absence of bacteriological data the determination of the oxygen demand of a stream above and below the point where an effluent is discharged is probably the best index of the effect of the sewage on the stream.

12. Sludge Analyses

Samples of sludge were taken at most of the plants visited, and complete analyses are presented in Tables Nos. 62 and 63 (pp. 176, 177).

For routine work determinations of moisture content and specific gravity are of importance. Where the sludge is being advocated for use as a fertilizer, total nitrogen determinations are of course essential.

In the interpretation of data on the specific gravity of sludge it is to be remembered that the specific gravity as determined analytically does not represent the specific gravity of the sludge when it is in the bottom of a tank under a head of 20 to 30 feet of water. On being brought to atmospheric pressure a good portion of the dissolved gases may be liberated, and this may affect the specific gravity to a considerable degree.

CONCLUSIONS BASED ON LABORATORY STUDIES

Sewage, analytically considered, may be conveniently resolved into its soluble or colloidal and its suspended or readily settleable constituents. Practically the aim of all methods of sewage treatment is the oxidation of the soluble or colloidal portion and the removal of the suspended or readily settleable portion as an inoffensive or even a marketable sludge. The aim of sewage analysis, therefore, should be to determine both the degree to which the removal of suspended matter has been effected and the state of oxidation of the soluble portion which is to be discharged into a stream. The suspended matter determination by the Gooch crucible method is very generally accepted as a satisfactory method for estimating the removal of the suspended matter. Opinions differ widely, however, in the choice of suitable methods for the estimation of the degree of oxidation effected, and it is believed that progress in sewage treatment is being greatly retarded by this lack of agreement.

Based on the results obtained during the survey and the results of extensive tests on industrial wastes and several river waters, it appears that the 5-day biochemical oxygen demand as determined by the excess-oxygen method is the best method available for estimating the strength of a raw sewage, the efficiency of the various devices used in sewage purification, and the quality of the effluents produced.

These two tests, the oxygen demand and the suspended matter, seem to be capable of furnishing about all the analytical data that is required for the proper operation of the ordinary sewage treatment plant, and are suggested as an irreducible minimum of laboratory work. At activated sludge plants the settleable solids and the ammonia nitrogen should be determined in addition. Other tests are of value as additional circumstantial evidence but should not be added to a routine schedule unless for research purposes or where special conditions make it necessary to do so.

In this connection it must be remembered that the analytical work during this survey was restricted to chemical studies. No mention is, made therefore, of the bacteriological tests, though it is appreciated that they are valuable and essential at some plants. Moreover, tests designed to furnish information as to the fitness of sludge for withdrawal do not seem to be developed sufficiently to warrant any definite recommendation.

Determinations of nitrogen in its various forms are time-honored procedures which furnish more or less useful indirect information but do not appear to be essential for efficient plant operation. These tests are generally time consuming, and, at best, furnish information on only half the polluting material present, the nitrogenous.

Nitrate determinations may be useful in estimating the quality of an effluent but of course can not be used for estimating the strength of a raw sewage. Ammonia nitrogen determinations are very readily made, using the direct method, but do not furnish very reliable information in most cases. Albuminoid ammonia and total nitrogen determinations, requiring considerable apparatus and time, can hardly be used to estimate the percentage purification effected by a plant. Their use for this purpose dates back to a time when no better methods were available.

The oxygen-consumed test furnishes information as to the amount of carbonaceous material present but does not include a considerable portion of the nitrogenous impurity, the ammonia nitrogen. If worked together, the various nitrogen determinations and the oxygen-consumed test can be made to give a fair idea of the degree of purification effected, but only with a considerable expenditure of time and effort which does not seem justified in view of the sometimes misleading results obtained.

The above discussion applies without much qualification to plants where chemists are employed. At some plants where chemists can not be employed the readily performed relative stability and settleable solids determinations are the safest and best fitted for the purpose of supplying the plant foreman with some information as to the strength of a raw sewage and the quality of an effluent.

CHAPTER IV

SUMMARY OF ENGINEERING DATA AND CHEMICAL ANALYSE OBTAINED AT THE PLANTS SURVEYED

I. Alliance, Ohio

The engineering survey of the sewage-treatment plant at Allia Ohio, covered the period May 26 to June 6, inclusive. The laborat work was started with the sample of June 1st and continued throu the sample of the 14th.

Alliance is a thriving industrial city located in the northeastern pa of Ohio on the main line of the Pennsylvania Railroad, and in 19 had a population of 21,603. The industries are largely those devot to the manufacture of machinery and heavy iron goods.

The sewerage system is built on the separate plan, but it is admitt that some down spouts are connected. The total contributi population is estimated at 20,000. The system as a whole is divid into two parts, the high-level system, serving about 95 per cent of t contributing population and feeding to the treatment plant by gravi and the low-level system, serving the remaining 5 per cent of t population and feeding to the site of an old sewage-treatment pla where the sewage, after passing through septic tanks, flows to pum at the main treatment plant, which lift it to the influent chann receiving the sewage from the high-level system.

The septic tanks at the old treatment plant probably affect the operation of the main plant little if any. They are not considered, therefore, as part of the treatment but as part of the sewerage system, serving as a protection to the pumps. There are three tanks each 80 by 40 by 6 feet deep, connected in series. The inlets and outlets are all on the same end, and, as there are no baffles, the sewage probably does not travel more than 15 to 20 feet of the 80-foot length. The tanks were last cleaned about five years ago. The effluent varies greatly, being at times very good and at other times black and highly septic.

Infiltration and leakage is claimed by local officials to be very high. Reference was made to a figure of 185,000 gallons per mile per day given by Metcalf and Eddy.[1] An investigation by the Ohio State Board of Health[2] brought out the fact that the sewage flow was at a rate of 246 gallons per capita per day. The excess above normal was attributed to leakage and excessive use of water in flush tanks.

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[1] American Sewerage Practice, vol. 1, p. 186, table 55.

[2] Report on an Investigation of Water and Sewage Purification Plants in Ohio. Ohio State Board of Health, 1908.

It is probable, however, that both of these figures quoted apply to the low-level sewers. Here there is evidence of excessive infiltration. As already stated, this system is estimated to serve only 5 per cent of the total contributing population, or 1,000 to 1,200 people, and yet about 25 per cent of the total sewage flow is received from it. While both the population and flow factors are estimates, they are probably accurate enough, within normal errors of estimation, to indicate that leakage on this system is very high.

Other data obtained during this survey would indicate that these conditions do not apply to the entire sewerage system, including the high-level sewers. The average flow for the year, May, 1919, to April, 1920, was at a rate of 124 gallons per capita per day, and the maximum for any day during that period was 214 gallons. If the entire excess of this last figure over a conservative estimate of 100 gallons per capita per day be considered leakage, without making any allowances for down spouts the average leakage for the entire system would be 2,000 gallons per mile per day.

Grades for sewers throughout the city are good. On the high-level system the average grade is 1 per cent with variations from 0.5 to 2 per cent, except that the main outfall sewer has a grade of 0.3 per cent. The average for the low-level system is 0.3 per cent.

Sewer cleaning is done almost entirely with fire hose. There are some flush tanks on dead ends, but most of these are idle.

The total mileage of all sewers in both the high and low level systems is 51.7. This is divided among the various sizes of pipe as given below.

	Lin. ft.		Lin. ft.
4-inch vit.	430	15-inch vit.	10,660
6-inch vit.	52,771	18-inch vit.	4,021
8-inch vit.	131,424	20-inch vit.	3,226
10-inch vit.	31,518	24-inch vit.	5,796
12-inch vit.	28,490	30-inch concrete	4,525

There are only 1,574 recorded connections to the sanitary sewers, but this is because records have been kept for only recent years. The city engineer, Mr. Homer Anderson, and the plumbing inspector estimate that there are in all from 4,800 to 5,000 active connections. This estimate is well checked by the water department which stated that there were about 5,200 active water connections, of which approximately 98 per cent served toilet facilities.

The sewage received at the treatment plant is typically domestic. That from the high-level system, constituting about 75 per cent of the total, is fresh, while that from the low-level system is, at times, very septic. When combined, however, the dilution of the septic sewage is great enough to give the mixture the characteristics of a fresh sewage. It has a whitish gray color and contains the usual floating and suspended solids consisting of paper, matches, matter, [illegible] vegetable skins, etc. There are no indicati any industrial wastes, confirming the claim that no waste-prod industries other than laundries contribute more than sanitary se

The average flow for the year preceding this survey was m. g. d., and the monthly averages vary little from this figure. maximum 24-hour flow for this period was 4.5 m. g. For periods during a day rates run as low as 1.5 and as high as 7.0 m

The following table contains the flow data for the year May, to April, 1920:

TABLE No. 18.—*Volume of sewage treated at Alliance, Ohio, for period in*

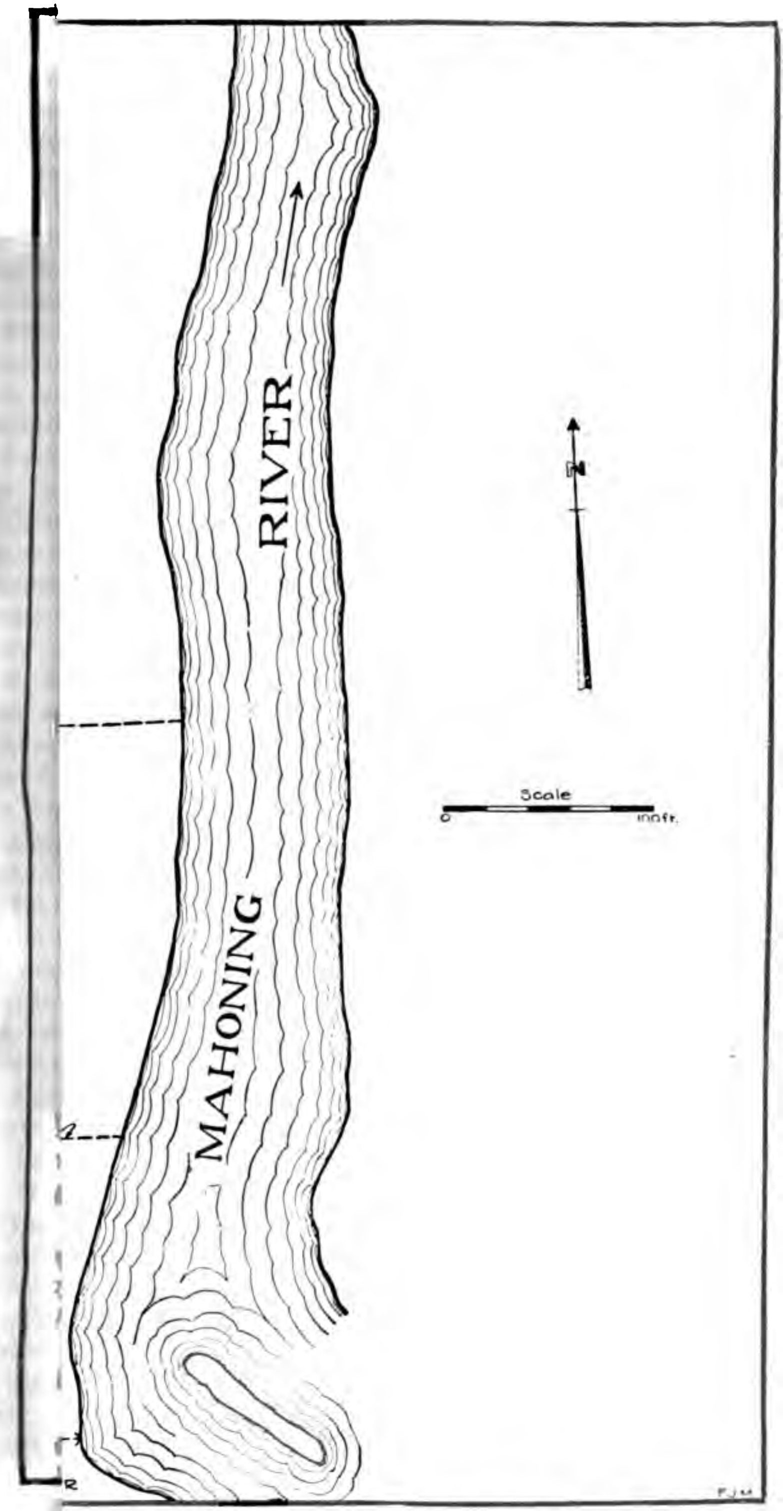
[Figures in million gallons per day]

1919	Average	Maximum	Minimum	1919-20	Average	Maximum	Mi
May	2.98	3.86	1.96	November	2.83	3.41	
June	2.61	3.09	1.60	December	2.90	4.50	
July	2.47	3.00	1.98	January	2.32	2.76	
August	2.50	3.43	1.98	February	2.40	2.80	
September	2.47	3.17	2.14	March	2.50	3.42	
October	2.85	3.87	1.98	April	2.58	3.65	

Sewage treatment was first started in 1893 with a chemical pr tation plant and sludge presses. This plant was abandoned, e for the septic tanks which have already been described in the cussion of the low-level sewerage system, and was superseded in by a plant, designed by Messrs. Bradbury and Shute, consisti grit chambers, bar screens, sedimentation tanks, contact beds, i mittent filters, and sludge beds. This plant is still operating, th modified, and, in some respects, enlarged in accordance with p prepared by Mr. R. W. Pratt in 1915.

As it now stands the original grit chambers act merely as infl channels, one chamber for the high-level sewage and another for low-level, which latter is pumped by a small automatic pum station located on the grounds of the treatment plant. The sewages are combined at the outlet of the old grit chambers and over a measuring weir to the bar screen. This screen is hand ra during the day as needed and left clean when the laborers leav night. There is no night operator. The screenings are remove a wheelbarrow to a dump on the plant grounds. About 4 to 6 cu feet of screenings per day or roughly 2 cubic feet per million gall are retained by the bar screen.

The screened sewage is distributed to one or both of two pl sedimentation tanks and to two Imhoff tanks, each of the la having four flow chambers. The plain sedimentation tanks are on a nine-day schedule. A tank is put into operation on Mond morning and run till a week from the following Wednesday, whe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is shut down, drained, and cleaned. In this way the two tanks are alternated, but on Mondays and Tuesdays of each week they are both operated. When a tank is taken out of service, the supernatant sewage is drained to a fine grain cinder filter reserved for this purpose and the sludge is then pumped by an ejector to the sludge chamber of an Imhoff tank for digestion. The total flow of sewage is divided roughly half-and-half between the plain sedimentation tanks and the Imhoff tanks.

The two Imhoff tanks are operated continuously. These tanks were constructed within an old sedimentation tank identical in design and construction with the two already mentioned. The bottom was taken out, hoppers built, and the Imhoff baffles placed, the longitudinal axis of the sedimentation tank being made the transverse axis of the Imhoff tank. The length of the sedimentation tank provided sufficient width for eight Imhoff flow channels, but as the digestion space is divided into only two sections, the tanks have been considered as two tanks with four flow channels each. The inlet and outlet channels are arranged to permit reversing the direction of flow.

In the operation of the Imhoff tanks, considerable difficulty has been experienced with the formation of scum in the flow channels. This appeared from the inspection to be due to one of or a combination of three causes: First, insufficient or too infrequent squeegeeing of the sloping bottoms of the flow channel; second, inadequate removal of sludge, which resulted in the sludge level rising above the bottom slot of the flow channel; and, third, agitation and pressure production in the digestion chamber by pumping sludge from the sedimentation tanks to the Imhoff tanks. The discharge line from the ejector serving the sedimentation tanks enters the Imhoff tanks from the top through the gas vents, but extends down into the tank about six feet. The entering sludge is, therefore, pumped into the Imhoff tanks with considerable downward velocity toward the sludge already in the digestion chamber. This stirs up the sludge and forces it back through the slots into the flow channel.

The sludge from the Imhoff tanks is run to an ejector which pumps it to glass-covered beds. There is available also some uncovered drying area but this is used very little. The operators appeared well satisfied with the glass-covered beds, stating that they were more independent of weather conditions than the open beds. However, the drying period was admittedly affected to some extent by seasons and weather. It averages from 8 to 14 days. Sludge is not measured in the tank or when run on the bed, but only when removed from the beds. As no determination is made of the moisture content, only a rough estimate of sludge production is possible.

The effluents from both the sedimentation tanks and the Imhoff tanks are combined and applied to 12 contact beds of ¼ acre each. These beds are arranged in three units of four each and dosed by automatic air controlled siphons, which rotate the doses on the four beds of each unit. The effluent from these beds during the late fall, winter, and early spring is discharged directly into the Mahoning River. During the warm months, however, it is again treated on three intermittent filters of one acre each.

Overflows and by-passes are available at various points to protect against flooding of the plant grounds or to cut out entirely the whole plant or any single device.

Rather inadequate laboratory facilities are provided in the laboratory of the water-filtration plant, about a half mile from the sewage plant. The room used for this purpose is small, making it very difficult to carry on the work of two departments by two different men. This condition has now (1921) been improved by placing the water-filtration and sewage-treatment plants under one chemist.

The personnel consists of the chemist, dividing his time between the water and sewage plants, and a superintendent with one assistant. For special work, such as weeding filter beds, cutting grass, etc., additional labor is provided. With the labor available, very little time can be devoted to the upkeep of the grounds.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 19.—*Results of chemical analyses at the Alliance, Ohio, sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample, ending 8 a.m.—	Suspended matter					Settleable solids, 2 hours c. c. per liter [1]				Oxygen consumed 30′ in boiling water				Alkalinity as $CaCO_3$ by M. O.				Ether soluble matter 24-hour comp. raw	Chlorine as chlorides			
	Raw	Effluent of tanks	Effluent primary contact beds	Effluent secondary fine cinder filters	Raw supernatant	Raw	Effluent of tanks	Effluent primary contact beds	Effluent secondary fine cinder filters	Raw	Effluent of tanks	Effluent primary contact beds	Effluent secondary fine cinder filters	Raw	Effluent of tanks	Effluent primary contact beds	Effluent secondary fine cinder filters		Raw	Effluent of tanks	Effluent primary contact beds	Effluent secondary fine cinder filters
June 2	130	74	18	----	26	4.0	0.1	Tr.	----	40	20	13.0	----	206	206	162	----	69	41	44	48	----
3	472	114	28	----	72	5.0	.6	Tr.	----	53	24	6.4	----	156	178	154	----	46	44	44	44	----
4	104	66	18	----	24	1.0	Tr.	Tr.	----	29	35	10.0	----	152	162	156	----	32	53	43	45	----
5	98	56	18	----	32	.6	Tr.	Tr.	----	30	22	19.0	----	158	178	150	----	27	42	42	40	----
6	104	55	21	----	35	1.6	Tr.	Tr.	----	34	26	9.6	----	172	188	156	----	28	47	50	48	----
8	150	70	22	----	50	2.0	Tr.	Tr.	----	52	29	15.0	----	176	200	178	----	42	44	40	46	----
9	160	71	----	----	32	1.8	Tr.	----	----	39	19	----	----	164	192	----	----	25	40	41	----	----
10	114	----	----	----	39	1.4	----	----	----	39	----	----	----	186	----	----	----	22	44	----	----	----
11	100	72	16	----	34	1.0	Tr.	Tr.	----	40	30	9.2	----	196	198	176	----	31	45	48	48	----
12	116	56	14	----	32	1.0	Tr.	Tr.	----	30	29	12.0	----	212	210	176	----	35	60	58	56	----
14	128	54	4	0	28	2.0	Tr.	Tr.	Tr.	34	18	6.3	5.4	198	200	174	162	45	54	53	51	53
15	----	67	14	0	46	2.0	Tr.	Tr.	Tr.	33	26	10.0	5.2	228	224	184	176	41	49	55	52	50
Average	152	69	17	0	37	2.0	Tr.	Tr.	Tr.	38	26	11.0	5.3	184	194	167	169	37	47	47	48	51

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[1] Tr. means less than 0.1 c. c.

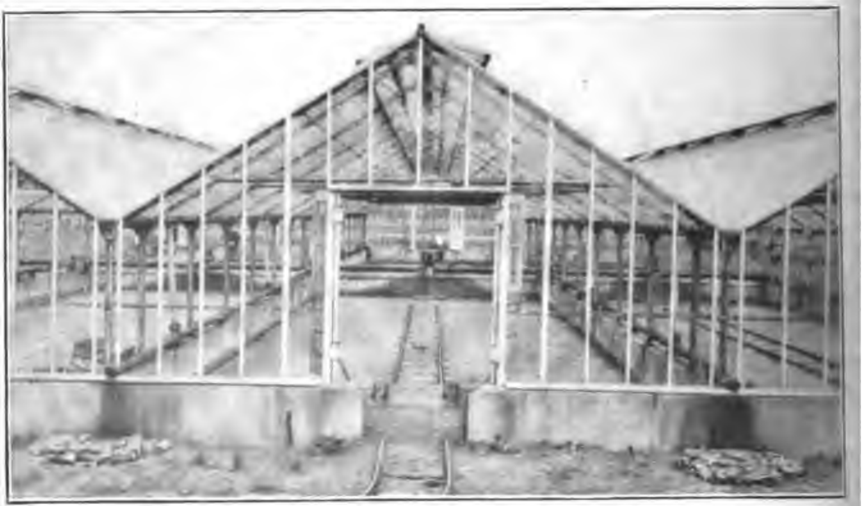


FIG. 2.—GLASS-COVERED SLUDGE BEDS AT ALLIANCE, OHIO

TABLE No. 19.—*Results of chemical analyses at the Alliance, Ohio, sewage-treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20°± C.								Dissolved oxygen			Hours to reduce M. B. at 20°± C.						Nitrogen as nitrates	
	Raw		Effluent of tanks		Effluent primary contact beds		Effluent secondary fine cinder filters		Raw	Effluent primary contact beds	Effluent secondary fine cinder filters	Raw		Effluent of tanks		Effluent primary contact beds		Effluent primary contact beds	Effluent secondary fine cinder filters
												Per cent concentration							
	1-day	5-day	1-day	5-day	1-day	5-day	1-day	5-day				10	20	10	20	5	100		
June 2	44	80	36	60	2.0	9.0	----	----	----	2.2	----	------	----	------	----	----	----	2.4	----
3	36	120	24	56	0.0	11.0	----	----	0.0	2.0	----	------	----	------	----	----	----	2.8	----
4	20	74	20	84	6.0	22.0	----	----	3.4	6.0	----	[1]264+	----	[1]264+	----	264+	----	3.2	----
5	22	74	16	56	6.0	19.0	----	----	2.5	4.6	----	[1]72	72	------	192	----	168	3.6	----
6	60	104	52	76	14.0	49.0	----	----	3.5	7.4	----	------	48		48	----	216+	3.2	----
8	56	124	40	92	16.0	34.0	----	----	4.2	5.8	----	------	----	------	----	----	----	2.2	----
9	20	86	16	44	----	----	----	----	4.3	----	----	------	44	------	69	----	----	----	----
10	24	60	----	----	----	----	----	----	4.2	----	----	72	45	------	----	----	----	----	----
11	36	84	28	76	5.0	15.0	----	----	5.4	8.5	----	144+	24	144+	24	----	144+	2.2	----
12	36	80	28	84	5.0	17.0	----	----	2.9	6.6	----	72+	24	72+	48	----	120+	2.0	----
14	34	78	14	34	0.5	6.5	1.4	4.6	1.6	7.4	9.1	72	48	------	----	----	----	4.5	5.0
15	44	144	40	88	6.0	16.0	----	6.1	1.4	7.0	8.6	------	48	------	48	----	----	1.6	3.0
Average	36	92	28	68	6.0	20.0	1.4	5.3	3.0	5.7	8.8	------	----	------	----	----	----	2.8	4.0

[1] 5 per cent.

The efficiency of the various treatment devices is made a separate section of this report, as is also a detailed discussion of the interpretation and value of different determinations. Only a few general remarks, based on the analyses in the above table, will, therefore, be made at this point.

The presence of dissolved oxygen in the raw sewage on all days except one confirms a statement previously made that the sewage is received at the plant in a fresh condition. This is further evidenced by the extent to which the settleable solids are removed in the tank, indicating that there is very little breaking up of these solids in the travel in the sewers to the plant. Besides being fresh, the sewage is rather weaker than the average. This is best shown by the 5-day oxygen demand results, which average only 92 parts per million with a maximum of 144.

The final intermittent filters were operated only the last two days of the studies. These, as already stated, were by-passed except during the warm summer months. The effluent from the contact beds is low in suspended solids, having an average of 17 parts per million, with a maximum of 28. The oxygen demand, both one and five days, taken with the high stability as shown by the methylene blue test, and the continued presence of nitrates, indicates an effluent satisfactory for the dilution requirements of the receiving body of to the Intrenchment Creek plant. 4. A 14-foot interceptor about 2½ miles long, running northeast to the Proctor Creek plant.

Each interceptor discharges into a natural watercourse, where the dry weather flow drops through a bar screen at the end of the interceptor to a 4-foot outfall sewer, which carries the sewage to the treatment plant. The two 4-foot outfalls to the Peachtree Creek plant join into one 4-foot sewer before reaching the plant. These sewers are large enough to carry the normal dry weather flow, but at times of storms only a relatively small portion of the discharge from the interceptors can be carried in them. The excess passes over the screen to the natural watercourses.

As a rule, after every heavy rain the screens are raked and the screenings, mostly brush, sticks, etc., left below the screens to be washed downstream by the next heavy storm.

Infiltration was stated to be appreciable in both types of sewers. It is probably sufficient to have some material effect upon the operation of the treatment plants. The normal dry weather flow averages around 160 gallons per capita per day, with a water consumption around 115 gallons. Infiltration is therefore a factor, even during dry weather.

The sewage from a small district served by sanitary sewers is pumped into the interceptor. This pumping station was built to operate automatically. The equipment consists of two Worthington vertical centrifugal pumps with 4-inch suctions and 3-inch discharge, rated at 300 gallons per minute, shaft connected to two 10-horsepower General Electric Co. motors. These operate intermittently, controlled by floats in the suction well. The static head of discharge is 40½ feet. This plant is not operated a considerable portion of the time, the sewage by-passing to a near-by stream.

Grades throughout the system are adequate. Those on trunk sewers vary from 0.3 to 1.0 per cent and on laterals from 1 to 12 per cent. Sewer flushing is carried on regularly. All sewers have flushing manholes with 2-inch water connections direct from the city mains. These manholes are so arranged that the outlet can be closed while the manhole is filled with water, which is released into the sewer through an 8-inch valve. In addition to this artifical flushing the majority of the sewers receive a thorough cleaning flush at times of heavy storms.

No detailed information of the lengths of the various sizes of sewers was available. The total mileage on January 1, 1920, was 333.6, of which about 208 miles is of the combined type and 125 of the separate type.

As the sewerage system of Atlanta is about 62 per cent combined and 38 per cent separate, the raw sewage is more nearly typical of combined than of separate sewage.

That received at both of the plants surveyed is typical of combined sewage, with its domestic sewage character during dry weather and its storm sewage character during wet weather. The rains in Atlanta are likely to be very intense and the run-off is rapid, so that the change in character of the sewage is extremely marked and sudden.

Industrial wastes are not considered to have much if any effect upon the operation of the treatment plants studied. With the exception of a small amount from a steel plant, practically no wastes are discharged into the sewers tributary to the Peachtree Creek plant. The Intrenchment Creek plant at times receives an alkali cotton scouring waste in sufficient quantity to give the sewage a distinct reddish color, but it is not believed by Mr. C. C. Hommon, supervising chemist, that treatment processes are noticeably affected by it.

The sewage is received at both plants in a fresh condition, containing, as a rule, at the Peachtree plant a trace of dissolved oxygen. The color, except as noted above, is the typical whitish gray during dry weather and muddy brown at times of storms.

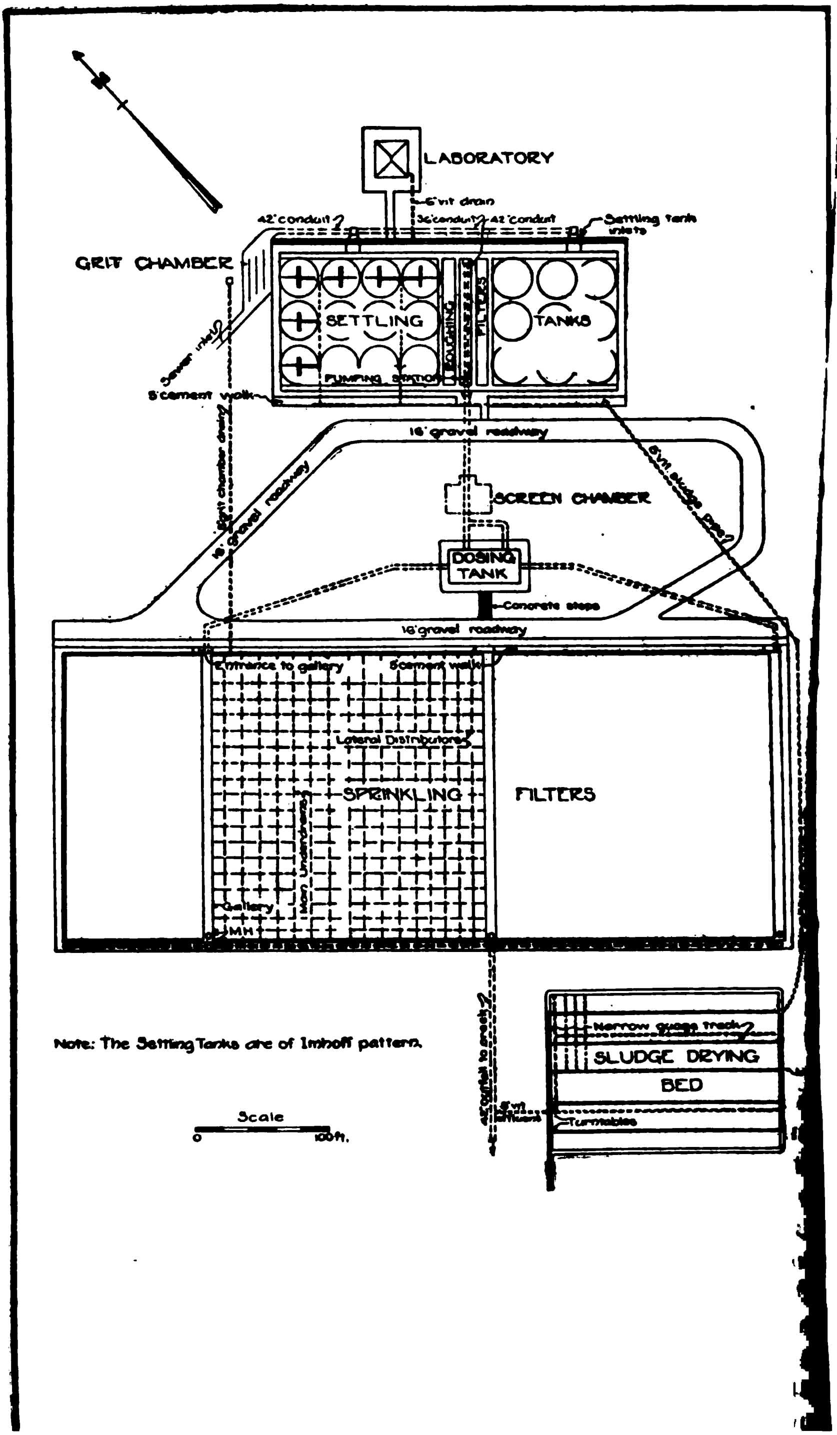
Floating material and solids caught on the screens are also normal, consisting of matches, fecal matter, sticks, leaves, rags, dead animals, etc.

The volume of sewage received at the two plants surveyed was not definitely known. During the war, 1917 to 1920, comparatively little attention or supervision was given to the plants, and the flow-measuring devices had been inoperative for an extended period previous to the survey. It was estimated, however, that the dry-weather flow to the Intrenchment Creek plant varied from 2½ to 6 m. g. d., averaging 5 m. g. d., and that to the Peachtree Creek plant varied from 8 to 16 m. g. d., averaging 12 m. g. d.

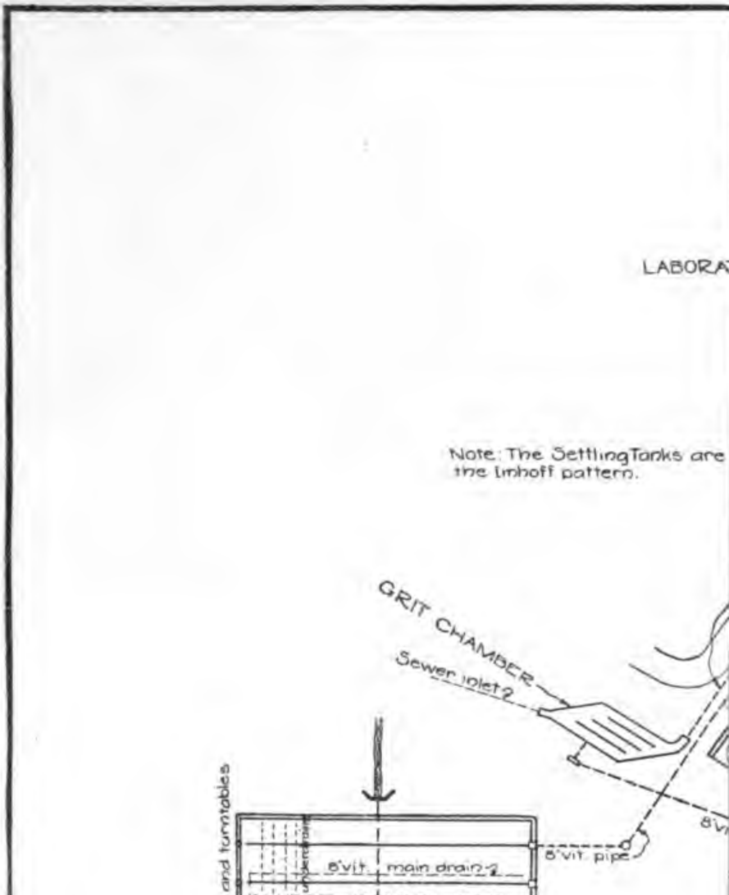
Previous to 1912 natural watercourses were used for the disposal of untreated sewage, resulting in an intolerable condition of pollution and nuisances. During that year the first treatment plant serving the west and northwest part of the city was installed. This was followed in 1913 and 1914 by the installation of two more plants for the major portion of the city. All plants were designed by Messrs. Hering & Fuller, and are, with the exception of size and a few minor details, identical.

There have been no important modifications made since the plants were constructed. They are operating now as when first put in service, with the exception that the use of certain devices has been discontinued as unnecessary.

The 4-foot outfall sewers discharge into receiving chambers at the plants and then through coarse bar screens into one of the grit chambers. From the grit chambers the sewage flows to the Imhoff tanks, 30 at the Peachtree Creek plant and 21 at the Intrenchment Creek plant. These are arranged in units, each having three tanks, operat-

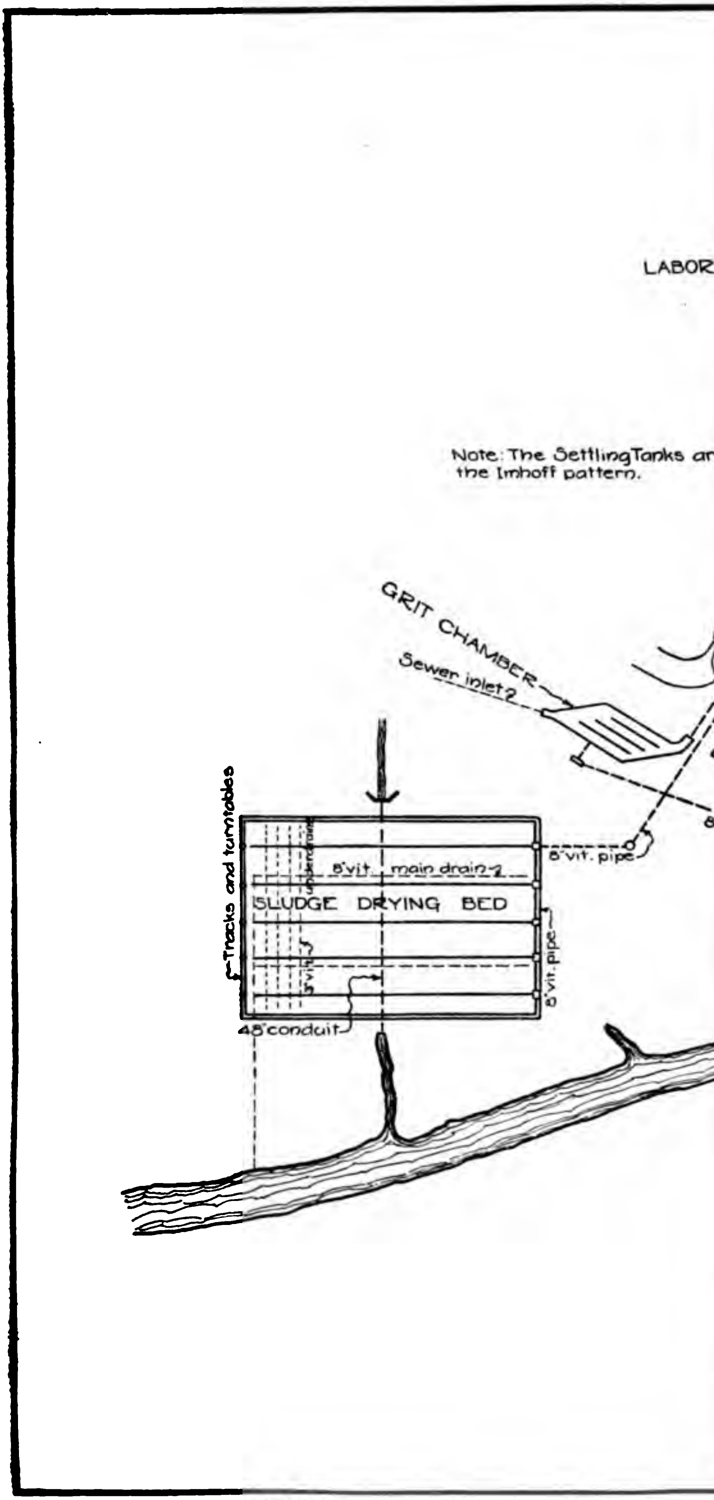

LABORATORY
6" vit drain
42" conduit
36" conduit
42" conduit
Settling tank inlets
GRIT CHAMBER
SETTLING
TANKS
ROUGHING
FILTERS
PUMPING STATION
Sewer inlet
5' cement walk
16' gravel roadway
Grit chamber drain
16' gravel roadway
SCREEN CHAMBER
6" vit sludge pipe
DOSING TANK
Concrete steps
16' gravel roadway
Entrance to gallery
5' cement walk
Lateral Distributors
SPRINKLING
FILTERS
Main Underdrain
Gallery
MH
42" outfall to creek
6" vit effluent
Narrow guage track
SLUDGE DRYING
BED
Turntables
Note: The Settling Tanks are of Imhoff pattern.
Scale
0
100 ft.

ing in series. [illegible]



Note: The Settling Tanks are
the Imhoff pattern.

99510°—25†. (Face p. 43)



Note: The Settling Tanks ar
the Imhoff pattern.

series. They are of the circular type with rectangular flow trs extending over the three separate tanks each with its own chamber. Crossovers permit reversing the direction of flow tanks. From the tanks the sewage is applied by siphons to g filters, of which the Peachtree Creek plant has 2½ acres and renchment Creek plant 2 acres. The effluents of the trickling oes direct to the receiving streams.

verflows and by-passes provided at various points, any one or ces can be by-passed, and during heavy storms all sewage is ged without any treatment direct to the streams. At the ee Creek plant some of the effluent from the tanks is by-around the filters as a matter of routine, as the filter installa-only approximately one-half the capacity of the tanks.

riginally built, roughing filters were provided between the nd filters to remove solids likely to clog the filter nozzles. short period of operation, however, their use was discontin-being superfluous.

al sludge bed areas are provided at both plants. At the In-ment Creek plant these are adequate to take care of the sludge ed, though some is occasionally run on fields and low-lying djacent to the plant. But at the Peachtree Creek plant the ed sludge-drying area is only about one-third that needed. s plant a great deal of the sludge is run into low-lying areas nt to the plant or is lagooned and held till times of very heavy s, when it can be safely discharged into the swift-flowing and n stream without creating any nuisances.

boratory facilities are provided at the Peachtree Creek plant, re analytical work for all the plants is conducted. It is adequate size and well equipped.

An interesting feature of the Peachtree Creek plant is the use of e gases from sludge digestion in the Imhoff tanks for lighting and eating. Several gas vents are capped with metal drums which are onnected to a standard gas-storage tank. The gas is used for light-ng the grounds, in the laboratory, and for heating and cooking in he house of the supervising chemist, which is located at this plant.

Operation of all treatment plants is directed by an exceptionally apable supervising chemist. Under him at the Peachtree Creek lant are three day laborers and a night watchman and at the In-renchment Creek plant a foreman, two day laborers, and a night atchman.

Few plants present a more attractive appearance than those at tlanta. While it was evident that the grounds had been somewhat eglected during the war period, when the supervising chemist was way, they showed the care and attention which had formerly been given them and were still in better condition than most pla relatively small amount of work will bring them back to ' plant condition.

The results of the chemical analyses made at the Intren Creek plant are contained in the following table:

TABLE No. 21.—*Results of chemical analyses at the Atlanta Intrenchme sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter			Settleable solids, 2 hours, c. c. per liter[1]			Oxygen consumed 30' in boiling water			Alkalinity as CaCO³ by M. O.			Ether soluble matter 24-hour comp. raw	Cl c
	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters		Raw
Sept. 2	96	30	19	3.1	0.6	Tr.	33	30	3.0	84	80	76	29	101
3	148	70	61	3.0	.3	Tr.	29	17	11.0	88	96	96	181	96
5	86	194	48	1.3	.1	Tr.	46	27	19.0	68	88	40	210	80
6	102	36	35	3.0	.2	Tr.	34	16	11.0	72	72	24	182	86
8	90	48	49	.5	.2	Tr.	25	20	6.0	78	86	36	88	78
10	114	42	48	2.0	1.4	Tr.	28	16	11.0	81	81	40	225	98
11	84	20	48	1.2	.3	Tr.	27	24	12.0	76	80	40	61	101
14	92	82	68	4.5	2.1	0.9	37	24	14.0	80	76	32	23	96
15	96	68	40	2.3	.6	Tr.	45	23	11.0	80	88	52	10	94
16	112	96	32	4.0	.5	Tr.	42	14	4.0	68	76	42	30	98
17	144	54	16	1.9	.5	Tr.								
Average	106	67	42	2.4	.6	Tr.	35	21	10.0	77	82	48	104	93

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.						Dissolved oxygen		Hours to reduce M. B. 20° ± C.			
	Raw		Effluent Imhoff tank		Effluent trickling filters		Raw	Effluent trickling filters	Raw		Effluent Imhoff tank	
									Per cent concentration			
	1-day	5-day	1-day	5-day	1-day	5-day			20	40	20	40
Sept. 2	16	36	12	32	0	3.6	0.0	4.5	[2]216+		[2]216+	
3	54	78		18		2.6	.0	5.7	[2]90		[2]192+	
5	48	188	8	20	.6	3.9		6.0	[2]360+		[2]360+	
6	10	12	6	10	1.9	2.7	.0	5.6	113	41	336+	89
8	8	30	4	20	4.3	5.8	.0	6.2	70	46	288+	46
10	26	54	8	20	3.1	5.8	.0	5.9	75	22	240+	22
11	13	52	9	28	2.3	5.2		4.9	41	41	90	18
14	26	50		38	3.1	4.5	.0	4.7	41	16	68	16
15								5.0	64	21	120+	21
16								5.8	39	23	96+	23
17												
Average	25	62	9.2	23	2.1	4.2		5.4				

---

[1] Tr. indicates less than 0.1 c. c.

[2] Dilution 10 per cent.

During the days covered by these analyses, there were heavy rains on the 2d, 3d, 6th, and 8th; traces on the 5th and 10th; but no rain during the remaining days of the tests. On four days, the 4th, 9th, 12th, and 13th, all sewage was by-passed to the creek. The analyses on the days the plant was operated indicated a weak sewage, probably due to dilution of storm and ground water. The suspended solids of the raw sewage are only slightly above 100 parts per million, and the 5-day oxygen demand only 67. The 1915 records at the plant, however, show an average suspended solids content of 140, which indicates that the sewage is normally stronger than indicated by the results tabulated.

The analyses in the above table show a very highly purified plant effluent with a 5-day oxygen demand of 4.3, a dissolved oxygen content of 5.6 parts per million, and a uniform retention of methylene blue color.

The results obtained at this plant as well as those at the Peachtree Creek plant are not considered as representative of normal dry weather conditions as those obtained from the other plants visited.

The results of the chemical analyses made at the Peachtree Creek plant are contained in the following table:

TABLE No. 22.—*Results of chemical analyses at the Atlanta-Peachtree sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter			Settleable solids, 2 hours, c. c. per liter [1]			Oxygen consumed $30'$ in boiling water			Alkalinity as CaCO^3 by M. O.			Ether soluble matter 24-hour comp. raw	Chlorine as chlorides		
	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters	Raw	Effluent Imhoff tank	Effluent trickling filters		Raw	Effluent Imhoff tank	Effluent trickling filters
Sept. 2	114	54	12	1.3	Tr.	Tr.	12	8	3	62	62	62	218	86	88	84
3	....	108	59	....	0.4	Tr.	....	20	3	....	64	56	....	84	86	92
4	908	54	54	9.0	Tr.	Tr.	60	15	4	76	74	30	97	88	88	88
5	426	173	59	4.8	.3	Tr.	62	22	13	48	40	24	78	80	85	84
10	224	80	62	.9	.2	Tr.	27	13	8	68	68	26	208	80	78	70
11	158	64	69	.4	Tr.	Tr.	30	21	11	76	78	30	79	78	82	82
12	94	47	16	1.5	Tr.	Tr.	29	18	6	60	66	26	94	83	90	88
13	54	36	27	.9	Tr.	Tr.	19	11	4	68	60	24	16	81	84	86
14	98	38	21	1.8	Tr.	Tr.	30	22	7	80	102	33	22	92	90	88
15	130	44	22	1.8	Tr.	Tr.	32	17	5	64	68	40	40	90	89	91
16	160	49	30	2.5	Tr.	Tr.	46	35	16	66	77	38	34	94	92	96
17	124	68	28	2.5	.5	Tr.	39	13	4	76	72	36	32	101	95	97
Average	226	68	38	2.5	.2	Tr.	35	18	7.0	68	69	35	83	86	87	87

[1] Tr. indicates less than 0.1 c. c.

TABLE No. 22.—*Results of chemical analyses at the Atlanta-Peachtree treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20°±C.						Dissolved oxygen		Hours to reduce M. B. a 20°±C.			
	Raw		Effluent Imhoff tanks		Effluent trickling filters		Raw	Effluent trickling filters	Raw		Effluent Imhoff tanks	
									Per cent concentration			
	1-day	5-day	1-day	5-day	1-day	5-day			20	40	20	40
Sept. 2	16	40	12	36	0.0	5.0	0.0	4.0	[1]122	------	[1]122	------
3	------	------	8	18	.4	4.0	------	5.0	------	------	[1]216	------
4	------	112	------	20	------	3.0	------	.0	[1]72	------	[1]192	------
5	24	88	8	12	.0	2.2	.0	7.3	67	------	[1]240+	------
10	5.8	24	2	4	1.7	2.3	.0	7.4	47	------	119	------
11	11	36	7	30	3.0	5.8	------	6.0	22	22	22	22
12	13	37	10	27	3.5	5.4	------	5.6	24	22	144	22
13	3	11	3	5	2.5	4.4	.0	6.4	168+	47	168+	96
14	32	68	18	30	2.0	3.7	.0	4.6	70	24	70	24
15	------	------	------	------	------	------	------	5.5	48	31	46	31
16	------	------	------	------	------	------	.0	5.8	70	24	96+	24
17	------	------	------	------	------	------	------	5.2	------	23	------	46
Average	15	52	8.5	20	1.6	3.9	------	5.7	------	------	------	------

[1] 10 per cent concentration.

The remarks already made concerning the results obtained Intrenchment Creek plant are largely applicable to the results above table. Heavy rains altered the character of the raw s and interfered with the operation of the plant to such an exte the results are not comparable with those obtained from th plants. The suspended solids in the raw sewage averaged 22 per million due to the excessively high results for the 4th and

With the exception of rather high suspended solids resul effluent from the trickling filter is exceptionally good. The oxygen demand is only 63 per cent of the dissolved oxygen c and methylene blue samples, even those kept for ten days, w decolorized.

It is difficult to secure cost data from various plants in suc that they will admit of comparison. At some only a lump-su for the whole plant is available, at others detailed unit prices obtained, and occasionally the cost of different devices is on Unit prices are too detailed to be included in a report of this At Atlanta it was possible to get the total cost of each plant a the lump sum of the main treatment devices. The engineerin however, was totaled for all three plants, and has been arb divided between the plants in the ratio of their total costs ex of land.

The following table has been arranged, covering this data two plants surveyed:

TABLE No. 23.—*Cost of construction of the Intrenchment Creek and the Peachtree Creek sewage-treatment plants at Atlanta, Ga.*

Item	Intrenchment Creek		Peachtree Creek	
	Cost	Remarks	Cost	Remarks
Year completed		1914		1913.
Land	$19,580		$24,475	
Grit chambers	2,500		2,750	
Imhoff tanks	31,900	21 tanks rated 5 m. g. d.	39,200	30 tanks rated 10 m. g. d.
Dosing tanks	5,000		5,000	
Trickling filters	85,784	2 acres	83,838	2½ acres.
Sludge beds	6,000		9,500	
Laboratory			2,000	
Roughing filters	12,000	Not operated	17,500	Not operated.
Engineering	29,200		35,300	
Other items	27,709		50,743	
Total	221,673		270,306	

Very little data on maintenance costs were available. In fact the only definite figure obtainable was that of $10,919.66 for supervision and labor for all three plants for 1919. During this year the supervising chemist was serving in the Army, and had returned only a week previous to the engineering survey, so that the above figure does not represent normal conditions. At the time of the survey, the salary of the supervising chemist had not been fixed, labor was receiving $75 to $80 per month, night watchman $77.50, and the foreman at the Intrenchment Creek plant $75, plus a house.

III. BALTIMORE, MD.

The engineering survey of the sewage-treatment plant at Baltimore, Md., was made July 19 to 27, 1920. The laboratory work followed a little over a month later, August 24 to September 4.

Baltimore is a city of 734,000 population (1920 census) situated at the head of Chesapeake Bay. It is an important railroad center, and one of the large ports for foreign trade on the Atlantic coast. In addition, there are located within and adjacent to the city many large industrial plants of varied types.

Previous to 1912 most of the sewage was collected in cesspools, which were periodically cleaned out. All drainage from houses except toilet waters was carried, for the most part, in open gutters, to near-by drains, which emptied into the harbor, and small open streams flowing through the city. This practice created an intolerable nuisance in the harbor.

The present sewerage system, built since 1906, is of the separate type. It is divided into two sections, the high level and the low level. The high-level sewage is collected in an interceptor, which discharges into a gravity outfall sewer to the treatment plant. The low-level sewage flows in two interceptors to a pumping station, where it is lifted to the outfall sewer carrying the high-level sewage. Each of these sections of the system contributes about one-half of th volume of sewage.

The pumping station is located near the heart of the dow business section. Sewage before entering the pumps is first through hoisting-cage screens and then through one stationa screen. There are four cage screens, which are placed so th sewage has to pass through at least two of them. It is p by three 27½ m. g. d., Bethlehem steel vertical, triple-exp plunger, crank, and flywheel pumps. A peculiar feature design of this station is the total omission of any overflows passes. A relatively short shutdown of the pumps would re disastrous flooding of the surrounding business section with s The average pumpage is 27 to 30 m. g. d., except on Sundays it drops to about 24 m. g. d.

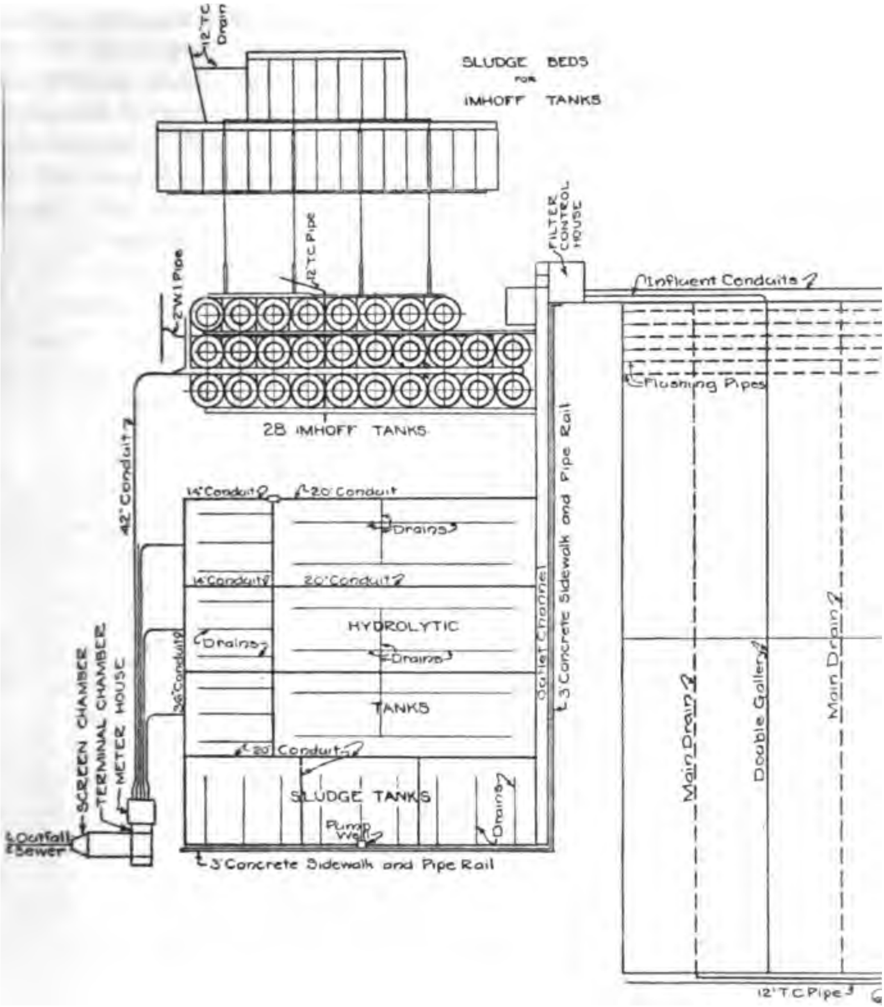
While the effects of storms are felt at the treatment pla infiltration through leaky sewers and manhole covers is very erate. Sewage flows at the plant also give no indication of ex infiltration. The absolute maximum rate of flow for the yea was less than twice the average daily flow for the entire year.

Grades of all sewers are computed to give a minimum v of 3 feet per second, lateral sewers under 18 inches averagin 3½ per cent.

For cleaning and flushing it was formerly the practice to m terminal manholes within 150 feet of a water main into fl manholes. These have a 1¼-inch connection to the water through which the manhole is filled, and the water is then r through a valve into the sewer. The terminal manholes th now being built are not being provided with flushing conne Some other manholes, besides the terminal ones, also have connections, and, in addition, there are three flush tanks system.

It was not possible to secure the mileage for the various s sanitary sewers, but the total to January 1, 1920, was 606.7 plus or minus 1 to 2 per cent. The total number of connecti the sewers, as of the same date, was 101,000. This figure sponds to an estimated connected population of 520,000, givi persons per connection.

The raw sewage received at the treatment plant is typica mestic, generally stale but occasionally containing a trace of dis oxygen. The observed color was a whitish gray, and the fl material and other suspended solids consisted of the usual ma pieces of soap and fecal matter, sticks, paper, fruit and veg skins, etc.


12" T.C. Drain
SLUDGE BEDS FOR IMHOFF TANKS
12" T.C. Pipe
2" W.I. Pipe
FILTER CONTROL HOUSE
Influent Conduits
Flushing Pipes
28 IMHOFF TANKS
42" Conduit
14" Conduit
20" Conduit
Drains
14" Conduit
20" Conduit
HYDROLYTIC
Drains
Drains
TANKS
36" Conduit
20" Conduit
SLUDGE TANKS
Pump Well
Drains
Outlet Channel
3' Concrete Sidewalk and Pipe Rail
SCREEN CHAMBER
TERMINAL CHAMBER
METER HOUSE
℄ Outfall Sewer
3' Concrete Sidewalk and Pipe Rail
Main Drain
Double Gallery
Main Drain
12" T.C. Pipe

into consideration. In 1912 the flow averaged only 12 in 1919 it was 55 m. g. d.

IV. Canton, Ohio

The engineering survey of the sewage-treatment pla Ohio, was made June 6 to 9, 1920. The laboratory stu shortly afterwards, June 23 to July 2.

Canton is a city of 87,091 population (1920 census), l northwestern part of Ohio, on the main line of the Penns road. It is an important industrial center with a variet types of manufacturing plants, those making iron and s however, predominating.

The sewerage system is of the separate type. It was s roof drains are connected to the sanitary sewers, and t storm or ground water reaching them is from leakage o This is well below the average over the country, as the been laid with special care and largely in dry trenches. industrial wastes are for the most part excluded, esp which might affect treatment processes. Occasionally, h amounts of oil wastes from unknown sources are receiv seriously interfere with proper operation of the plant.

The grades are, for the most part, sufficient to provi ing velocities. Those for laterals average 0.5 to 0.6 pe for the subtrunk sewers run as low as 0.2, and that for t the treatment plant is 0.1 per cent.

Cleaning and flushing is done by flush tanks or by l combination of direct water connection and flush t tanks are installed on new sewers, but, as the flow of sew sufficient for self-cleaning, the automatic feature of the f dispensed with, and they are turned on and off as occasi Hose flushing is comparatively limited. There is no regu sewers being flushed only when they become stopped.

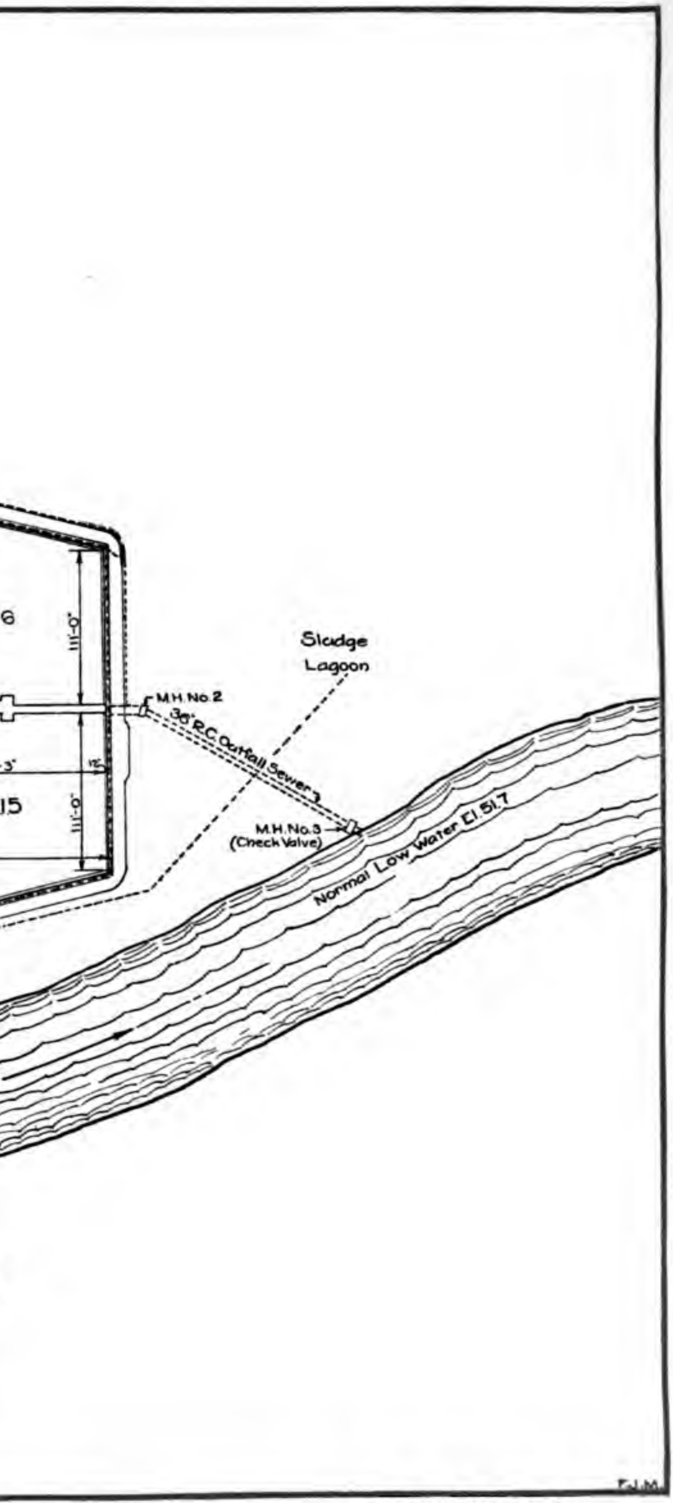
The total mileage of all sewers is 163, of which ab consists of 4-inch house connections. Below are listed of the various sizes of pipe included in the system.

4-inch, 109,000 linear feet.
6-inch, 189,600 linear feet.
8-inch, 439,100 linear feet.
9-inch, 5,600 linear feet.
10-inch, 35,900 linear feet.
12-inch, 8,600 linear feet.
15-inch, 38,700 linear feet.

Egg-shape, 3,300 line egg-shape sewer has vertical diameter of 4 horizontal diameter of 2 and invert radius of 3¾

(About 90 to 95 per house connections.)

There are on record 15,737 sewer connections. Some idle and a few are storm connections, but there are also a connections not of record. The local estimate of a sanitary connections is 15,700.


6
111'-0"
-3'
12"
15
111'-0"
Sludge
Lagoon
M.H. No. 2
36" R.C. Outfall Sewer
M.H. No. 3
(Check Valve)
Normal Low Water El. 51.7
F.J.M.

ve points on the system overflows have been provided to take flows in excess of the capacity of the sewers; one is on an line, two on 10-inch, one on an 18-inch, and one on a 20-inch. operate probably once or twice a week, but the volume of thus discharged into Nimishillen Creek is not known. In n to these overflows, there are two by-passes whereby all the can be diverted into the creek.

raw sewage received at the plant is strictly sanitary, plus a ly small volume of ground water from infiltration. That the tion is low is evidenced by the data in Table No. 26 below, shows that the average daily flow varied less than 1 m. g. d., maximum and minimum were less than 2 m. g. d. apart.

e is a threé-hour travel in the trunk sewer from the city to nt. This, added to the period in city mains and laterals, is nt to produce some septic action. The odor on the days of ion was that of slightly septic sewage. The suspended was well broken up and more or less water-logged, so that as but little material floating on the surface.

material caught on the screens consisted of paper, matches, d vegetable skins, fecal matter, etc. There was no indication strial wastes, confirming the statement that all such had been ted from the sanitary sewers.

n still and under cover of the building over the screen and ambers, the color was a bluish black, but in direct light in the o the tanks it was a deep gray.

following flow readings were available for the period of one receding the inspection. The estimated extreme rates were ½ m. g. d. for minimum and maximum, respectively.

No. 26.—*Volume of sewage treated at the Canton (Ohio) sewage-treatment plant*

low in million gallons	Month, 1919-20									
	June	July	Sept.	Oct.	Nov.	Dec.	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
r month	4.56	4.97	4.42	4.07	4.37	4.25				4.41
day for month	5.00	5.66	4.72	4.55	4.78	4.77	4.31	5.06	4.53	4.80
day for month	4.23	4.67	4.02	3.85	4.04	3.80	3.91	4.01	3.75	4.07
								10 days.	14 days.	11 days

ing gage not working regularly.

treatment plant was designed by Mr. R. W. Pratt, consulting er of Cleveland, Ohio, in 1914, and was put in operation in hough not complete in all details by that date. Since the l contracts have been completed some changes and improve- have been made and others are in contemplation for the near

The plant is located about 8 miles in a southerly direction fro center of the city. The outfall sewer is 3½ feet in diameter, concrete and partly segment block. At the entrance to the it becomes rectangular, 4 feet wide and 18 inches deep.

The sewage enters a small chamber from which it is diverte one of two channels containing coarse screens with ¾ to 1 inch openings. At the outlet of the screen chamber there is a reco device to measure the flow over the weirs.

These weirs discharge into two grit chambers, a weir for chamber. They are equipped with adjustable or false botto baffles running longitudinally.

The screen and grit chambers are inclosed in a substantial building vented by a high stack to reduce odors. Provisio also been made in this building for the installation of an incin to burn screenings.

The grit chambers outlet into a long flume which carrie sewage to the Imhoff tanks. There are six of these tanks arr in two sets of three each. In each set the three tanks can be ope in parallel or series. If operated in parallel, the direction o can not be reversed, but when in series, while the direction o in the separate tanks can not be reversed, the order of the tw side tanks can be changed, so that either one can stand as fi third in the series. Under normal operation the tanks are conn in series. The individual tanks are rectangular in shape and double flow chamber type with a central gas vent running the length of the tank.

The final treatment device following the Imhoff tanks consi contact beds. These are arranged in 16 units of one-half acre, ing 8 acres in all. The material in the beds is crushed slag, gravel around the distributing duct. The beds to be used are se by the operator, the inlet to each bed being controlled by a operated valve. An alarm bell gives notice of the filling of and the inlet is then closed by hand. The contact and disc periods are automatically controlled by siphons. The efflu discharged to a main collecting gallery and thence in a rectan sewer into Nimishillen Creek.

For sludge treatment there were, at the time of inspectio specially prepared sludge beds, each 150 feet long by 24 feet and provided with narrow gage tracks for loading cars with sludge.

The filtering material consists of 15 inches of sand laid over g the depth of the gravel varying from zero at the sides to 6 inc the middle, down which a 6-inch drain is laid in a trough. drain discharges directly into the creek. As originally constr no special bottom was laid. After a period of operation, how

al beds have been modified by the installation of concrete
ms.

ree of the six beds have glass covers of standard greenhouse
ruction. The purpose is to give 12 months use of the beds and
otect drying sludge from rain.

e six beds, described above, have not been adequate to handle
udge produced. A sludge well has, therefore, been installed
which sludge is pumped to low-lying areas or onto fields. In
ion, at the time of the inspection more sludge beds were being
red. No special bottom or filtering material was to be used, as
oil is a natural gravel and, it is felt, will drain readily. The
ruction, therefore, is to consist in removing the topsoil and
ng the chosen area. These beds are 54 feet wide and of a total
a of about 700 feet, divided into five beds 125 to 150 feet long.

boratory facilities are provided at the plant, one room of a
al administration building being devoted to this use. The
ment, however, is inadequate for properly carrying out this
of the work.

e city engineer has general supervision over the plant, the direct
tion being under a superintendent directed by the city engineer.
uperintendent is interested in the plant, and is giving excellent
vision. The city engineer gives the treatment plant much
personal attention than is generally customary where there is a
ntendent on duty at the plant. In addition to the super-
lent there are four regular laborers, and others as needed. The
tory is under a part-time chemist, who spends three days a
at the plant.[6]

general appearance the plant might be termed a "show"
The grounds are well taken care of, attractively planted and
clean.

---

the survey a full-time chemist has been employed.

The results of the chemical analyses made at this plant a tained in the following table:

TABLE NO. 27.—*Results of chemical analyses at the Canton (Ohio) sewage-t plant*

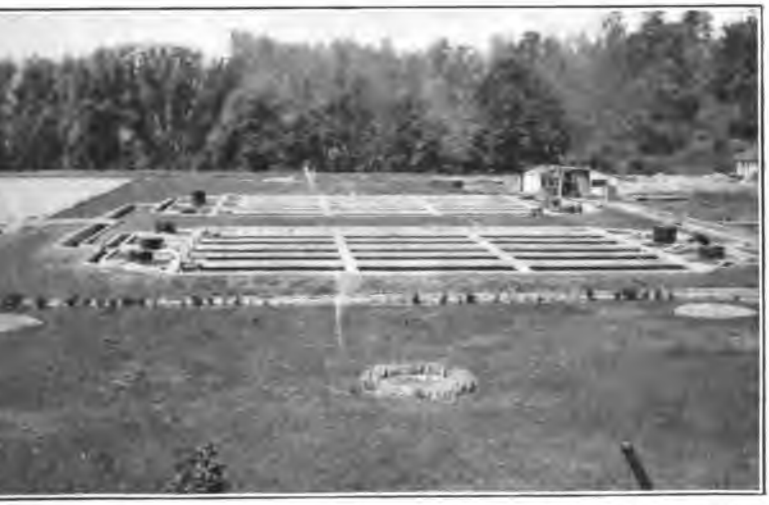
[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter				Settleable solids, 2 hours c. c. per liter[1]			Oxygen consumed 30' in boiling water			Alkalinity as $CaCO_3$ by M. O.			Ether soluble matter 24-hour comp. raw
	Raw.	Effluent Imhoff tanks	Effluent contact beds	Raw supernatant	Raw	Effluent Imhoff tanks	Effluent contact beds	Raw	Effluent Imhoff tanks	Effluent contact beds	Raw	Effluent Imhoff tanks	Effluent contact beds	
June 23	216	96	48	54	5.5	1.0	------	67	41	23	320	320	332	52
24	244	88	46	56	5.5	0.2	Tr.	59	41	16	336	340	336	59
25	256	84	38	56	5.0	.1	Tr.	62	42	20	352	340	352	61
26	250	72	40	71	5.0	.1	------	55	31	16	354	352	356	----
27	252	72	34	44	5.0	.2	Tr.	61	38	16	348	348	348	59
28	208	84	32	64	4.5	.1	Tr.	61	27	11	340	360	376	45
29	280	120	48	92	4.5	.2	Tr.	63	53	30	348	360	372	90
30	256	96	44	52	4.5	.3	Tr.	62	34	16	336	340	352	64
July 1	388	108	44	90	5.0	.5	Tr.	57	34	16	336	332	352	65
2	260	108	32	46	8.5	.5	Tr.	60	37	18	348	340	360	68
Average	261	93	41	62	5.3	.3	Tr.	61	38	18	342	343	354	62

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ±C.						Dissolved oxygen		Hours to reduce M. B 20° ±C.				
	Raw		Effluent Imhoff tank		Effluent contact beds		Raw	Effluent contact beds	Raw		Effluent Imhoff tank		Eff con b
									Per cent concentratio				
	1-day	5-day	1-day	5-day	1-day	5-day			5	10	5	10	20
June 23	92	176	72	120	16	42	------	0.3	----	----	------	----	----
24	112	168	96	132	16	37	------	.2	----	52	------	42	216
25	112	248	80	196	23	51	0.0	.5	72	24	120	50	96
26	120	200	65	100	19	32	.4	------	48	26	101	26	144
27	110	195	85	110	16	28	.0	.5	72	44	120+	44	120
28	135	185	80	125	14	33	2.2	1.8	52	24	120+	24	96
29	130	260	95	145	23	43	.0	------	----	----	------	----	----
30	105	225	65	115	18	41	.0	.8	54	22	120+	48	120
July 1	130	280	90	155	17	41	.0	.0	96	24	120+	30	120
2	135	190	70	90	12	22	1.2	1.2	----	----	------	----	----
Average	118	213	80	129	17	37	.5	.7	----	----	------	----	----

[1] Tr. indicates less than 0.1 c. c.

The raw sewage is one of the strongest studied during the s A comparative discussion of the sewage analyses obtained different plants is to be found in chapter V, page 117 et se it can be stated here that the suspended solids content was e or exceeded at only two plants, the oxygen consumed a plants, while the oxygen demand was not equaled anywhere.



8.—IMHOFF TANKS AND CORNER OF CONTACT BEDS AT CANTON, OHIO

The tanks removed 63 per cent of the suspended solids, effected a 38 per cent reduction in the oxygen consumed, and 42 per cent reduction in the oxygen demand, but notwithstanding this the tank effluent was stronger than was the raw sewage at several other places.

In spite of the strength of the tank effluent, the contact bed effluent contained less suspended solids than the average trickling filter studied. Though the per cent removal of the solids was not as great as that accomplished by the contact beds at Alliance, Ohio, the other contact installation studied, the actual amount of solids retained in the beds was exactly the same for both places; that is, 52 parts per million. The oxygen demand was rather high, and the nitrification, as evidenced by the nitrates, was low.

Nimishillen Creek, the receiving body of water, has an estimated minimum flow of 20 second-feet. Any normal stream of this size could easily take the load of the plant effluent without creating any nuisance or being rendered unsuitable for any except water-supply purposes. But Nimishillen Creek is badly polluted with industrial wastes and some sewage before reaching the treatment plant, so that physically the appearance of the plant effluent was better than that of the water in the creek.

The available cost data are mostly on the basis of unit prices, so that it is almost impossible to separate the totals among the various devices. Thus, though the actual construction of the Imhoff tanks is a lump-sum bid, the excavation is not included, and the excavation item includes also that for the contact beds. The total construction cost of the original plant was $272,472, to which must be added the cost of the land, $25,107, which includes a farm at $13,782, purchased to avoid a damage suit, together with the cost of buildings and other permanent improvements, amounting to $18,621. This gives a complete total of $316,200 for the treatment plant alone, not including the outfall sewer from the city to the plant. On a designed capacity of 6 m. g. d., the above figure is equivalent to $52,700 per m. g. d. capacity.

The operation and maintenance costs for the year 1919 were $10,948, divided as follows:

Supervision and labor	$8, 947
Tools, supplies, incidentals	1, 531
Horses and wagons	470

It should be noted, however, that these figures include some work done on the city's farm at which the plant is located, the item of horses and wagons being almost entirely chargeable to this. On the other hand interest, depreciation, and clerical services are not charged to the plant. Accepting the total as actually charged against the plant, the cost per million gallons treated was about $6.75.

V. Columbus, Ohio

The engineering survey of the sewage treatment plant at C bus, Ohio, was made July 28 to August 2, 1920. The labo studies followed about two months later, October 1 to 12.

Columbus is a progressive city of 237,000 population located central part of Ohio on the Scioto and Olentangy Rivers. It State capital, seat of the State university, and an important ra and industrial center, the industries including starch work manufacturers, tanning, iron and steel mills and fabricators, eries, creameries, and wool-scouring plants.

The sewers of Columbus are partly of the combined and pa the separate type. The main sewerage district, comprising 80 per cent of the area of the city, takes in the territory east adjacent to the Olentangy and Scioto Rivers. This district is se on the combined plan. The collecting sewers discharge into an ceptor, provided with overflows by which most of the storm by-passed direct to the rivers. It discharges into the main s pumping station.

The east-side sewer district, lying adjacent to Alum Creek, on the combined plan. The sewage from this section is carried east side pumping station, which lifts it into the sewer system main sewerage district. Arrangements are made in this distr the overflow of excess storm flow or the by-passing of the enti into Alum Creek during high water in the creek. The force from the pumping station to the interceptor is 20 inches in dia and 8,180 feet long.

The west-side sewerage district includes that part of the cit of the Scioto River. This district is sewered on the separate Both the storm and sanitary sewers drain to the main sewage ing station. The storm sewer, however, discharges directly in river except when the river is high, when it is pumped to the The sanitary sewage, together with that from the main inter including the east-side flow, is pumped to the sewage treatment during the warm months, which is the only time the sewage is tr During the winter months all sewers discharge direct to the except, as noted above, that from the west side, which has pumped to the river when the river is higher than the outlet west-side sewers.

Infiltration is considered to be about average, except duri cessive rainfall, when this factor runs high.

The grades on the west-side sewers are for the most part flat, the laterals running 0.3 per cent and the trunk sewer abou Conditions are better on the east side. Here the average grad 0.4 to 0.6 with variation from 0.3 to 2 and 3 per cent.

Cleaning and flushing is done mostly by hose and is practiced as a rule only when stoppages or odor nuisance occur. There are, however, some 150 to 200 flush tanks on the system, but these do not operate continuously or automatically.

The 1919 annual report shows a total of 397 miles of sewers. Since that time about 10 to 15 miles have been added, making a total for July, 1920, of about 410 miles. Detailed data covering the amount of various sizes were not available.

The 1920 census gives Columbus a population of 237,000. Of this t is estimated that 95 per cent, or about 225,000, are connected to the sewers. There is no accurate record of the connections to the sewers, but the waterworks department records show about 41,000 water connections as of January 1, 1921, and this probably is a fair estimate of the number of sewer connections.

The main sewage pumping station is located on the west side of and adjacent to the Scioto River. The east-side intercepting sewer, the west-side sanitary sewer, and the west-side storm sewer all discharge at this point. All the sewage to be treated is pumped from here to the treatment works. This includes all the sanitary sewage of the city and a part of the storm flow, the strictly storm sewage rom the west side discharging directly into the river.

In addition to pumping sewage to the treatment works this station s also used, during high stages of the river, to pump all the drainage of the west side to the river. This is necessitated by the low elevation of the west-side sewers, the east-side interceptor being high enough to discharge into the river by gravity even at the high stages of the river.

The sewage entering this station is first passed through one of two sand catchers or grit chambers each 8 feet wide by 90 feet long, with a depth varying with the position of the outlet gate. A derrick with grab bucket is provided for cleaning.

From the sand catcher the sewage passes through a 4-inch grid or coarse bar screen and then through two vertical bar-cage type screens n series, the first with 1-inch openings between ¾-inch bars, and the econd with ½-inch clear openings between ⅜-inch bars. These are et under the floor of the pumping station and hoisted by an electric motor for cleaning.

The pumps and power equipment are as follows: Three De Laval centrifugal pumps of 5, 10, and 15 m. g. d. capacity, direct connected o 50, 100, and 150 horsepower, respectively, General Electric motors; one Morris centrifugal pump of 15 m. g. d. capacity, direct connected o a 150-horsepower General Electric motor; and one Worthington centrifugal pump with Weinman impeller, direct connected to a 75-horsepower General Electric motor. All pumps are single-stage, double-suction, closed-impeller type, and all motors variable speed lip-ring type.

The static discharge head is 23½ feet, and the total for a pumping 28 feet. The flow is measured by a 48-inch integ Venturi meter, which is read every two hours. The force m the treatment plant is a 48-inch line 6,336 feet long. The m the river is a 48-inch line 330 feet long.

The east side sewage-pumping station is located at Main an low Streets. This is provided with one grit chamber giving second detention at a 5-inch per second velocity. It is cleaned twice a month by an orange-peel grab bucket without interr of operation.

Following the grit chamber are two vertical bar, cage-type screens 4 feet 1⅜ inches high by 2 feet 10¾ inches wide, with t screens flaring upstream to a width of 4 feet 6 inches. The b ¾-inch square with 1-inch clear openings. These screens are in series and operated simultaneously. When cleaning is ne they are hoisted to the main floor from the pit by a small and raked by hand.

The pumping and power equipment consists of two 10-inch man horizontal, single-stage, double-section, open-impeller c ugal pumps, direct connected to 100-horsepower variable General Electric motors.

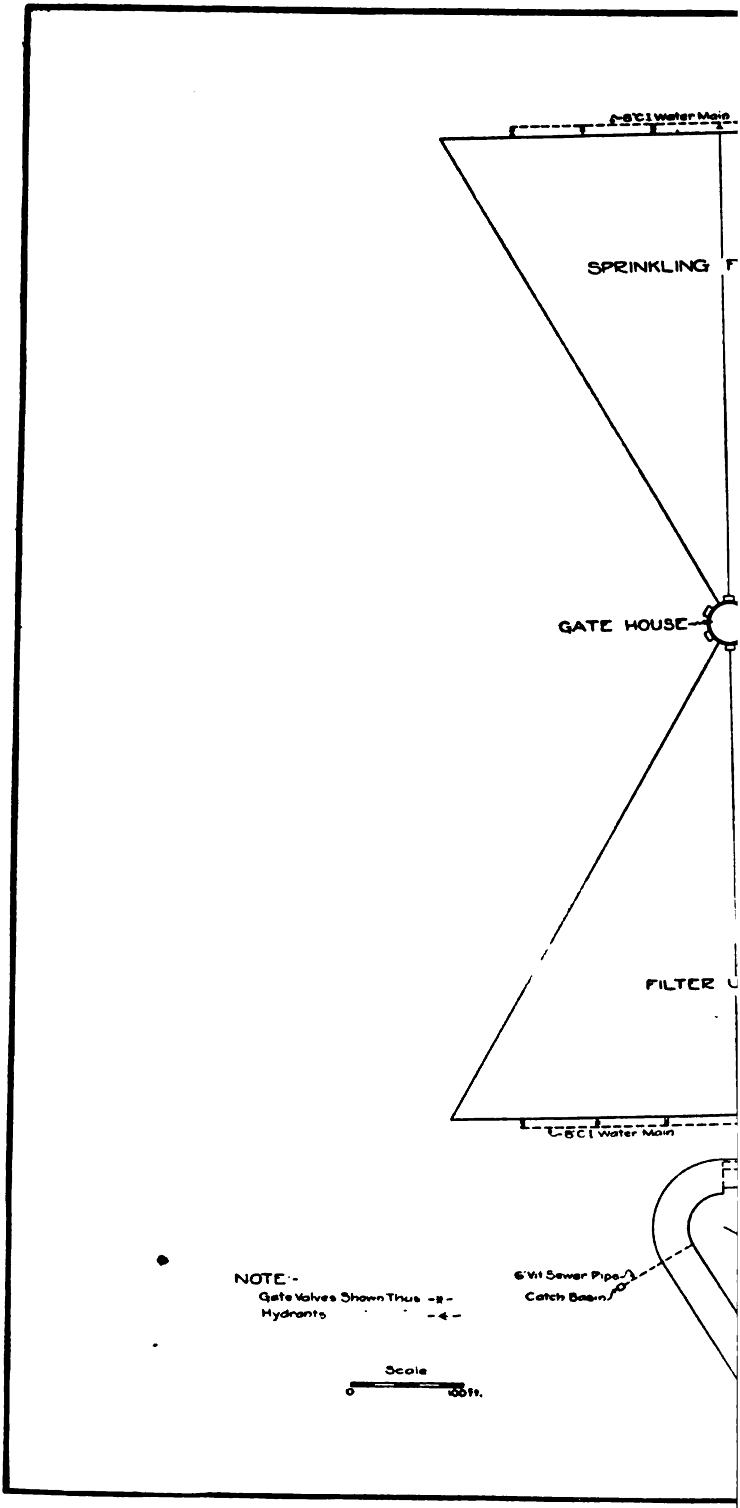
The static head is 52 feet, and the total 62 to 65 feet for a pumpage. The force main is a 20-inch line 8,180 feet long. flow is measured through a 20-inch integrating Venturi meter is read hourly.

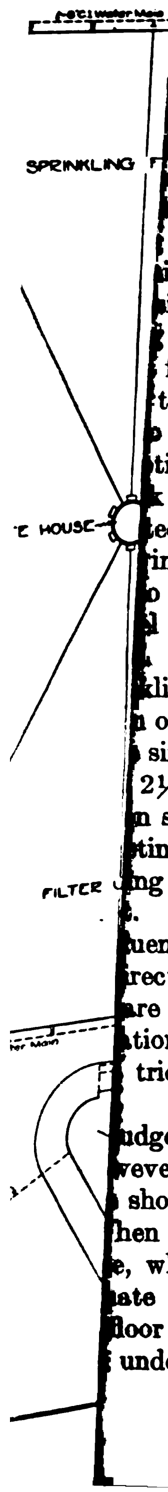
The sewage received at the treatment plant is from both co and separate sewers, that from the combined sewers predomi All of it is pumped once and some of it twice. In appearanc typical of the two types of sewage. During dry weather, wh flow is almost entirely sanitary, it has the common milky gra with the normal suspended solids, paper, fecal matter, m corks, etc., and during storm periods the color is a dirty yello

Industrial wastes tributary to the sewers include those fro pickling processes, starch works, tanneries, slaughterhouses, eries, wool scouring, and brewing. Of these, only that fro starch works is visibly detectable at the treatment plant. gives, at times, a milky white color to the sewage. It is n lieved by those in charge of the plant that this waste or any others are of sufficient volume to materially affect the opera any of the treatment devices.

In 1920 the average daily flow treated was 21.2 million g This flow is applicable only to a period of 196 days from M December, as the plant is not operated during the winter m

For the unsewered sections of the city, night soil disposal is pr free of charge, and, in addition, night soil for a section witho


8"C I Water Main
SPRINKLING F
GATE HOUSE
FILTER
8"C I Water Main
6"Vit Sewer Pipe
Catch Basin
NOTE:-
Gate Valves Shown Thus -ı-
Hydrants -ᐊ-
Scale
0
100 ft.



taken care of at the city station. For this latter serv-
of $2 per load is made for disposal. In 1919 a total
were handled. This figure covers the entire year,
t all of it was received at the treatment plant.

l sewage-treatment plant, designed by Mr. J. H.
neer for Messrs. Hering & Fuller, was put in operation
ny minor changes have been made from time to time
ortant alteration, that of converting the septic tanks
anks, was made in 1915 and 1916.

discharged at the plant from the 48-inch force line
in pumping station. As already described, preliminary
isting of sand catchers and bar screens, are located at
stations.

force main the sewage enters the distributing conduits
to the 22 Imhoff tanks. These are of three different
structural requirements in rebuilding them out of the
tic tanks. The effluent from these tanks passes to a
from which it is applied to the trickling filters by a
ted dosing mechanism. A float indicates the height of
in the storage well. At a certain elevation in this well,
the filters are opened by hand. Dosing is continued
has dropped to an established point, and the gates are
.

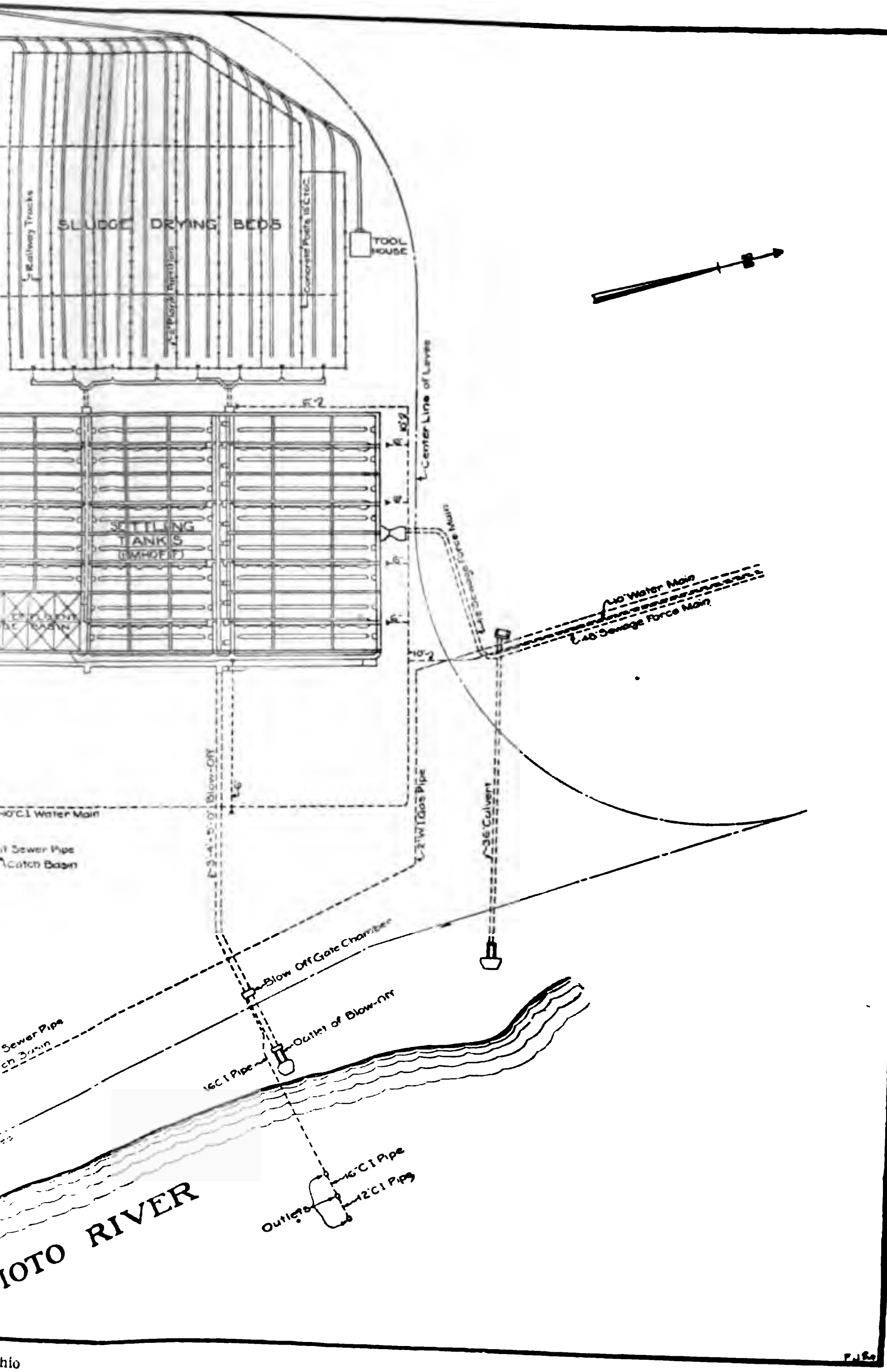
ling filters are in the shape of equilateral triangles laid
of a hexagon with the control house at the center. Only
six triangular units have been constructed. Each covers
2½ acres, divided into two filters of 1¼ acres each. The
n system is laid on the bottom with risers to the nozzles.
ting system consists of half tile laid on sloping bottoms.
ng material is 1 to 3 inch stone laid to an average depth
.

uent from the trickling filters is carried in a 66-inch circular
rectly to the river.

re in place, as part of the original plant, two secondary
tion tanks which were designed to receive the effluent
trickling filters. These, however, are now regularly by-

dge-drying beds are adjacent to the Imhoff tanks; their
ever, is only one-third to one-quarter large enough. The
shoveled into cars run on tracks down the center of each
hen filled the cars are hauled by a gasoline locomotive up
, where they are dumped on the slope.

ate laboratory and office facilities are provided on the
loor of the filter-control house. The supervision of the
under a competent chemist, with a regular personnel con-


SLUDGE DRYING BEDS
Railway Tracks
2" Plank Partitions
Concrete Posts 15' C to C
TOOL HOUSE
Center Line of Levee
SETTLING TANKS (IMHOFF)
EFFLUENT BASIN
Sewage Force Main
10" Water Main
48" Sewage Force Main
10" C.I. Water Main
Sewer Pipe
Catch Basin
3'4"×5'0" Blow-Off
2" W.I. Gas Pipe
36" Culvert
Blow Off Gate Chamber
Outlet of Blow-Off
16" C.I. Pipe
16" C.I. Pipe
12" C.I. Pipe
Outlets
IOTO RIVER

hio

mits is taken care of at the city station. For this latter serv- charge of $2 per load is made for disposal. In 1919 a total) loads were handled. This figure covers the entire year, ence, not all of it was received at the treatment plant.

original sewage-treatment plant, designed by Mr. J. H. ry, engineer for Messrs. Hering & Fuller, was put in operation 8. Many minor changes have been made from time to time ne important alteration, that of converting the septic tanks mhoff tanks, was made in 1915 and 1916.

age is discharged at the plant from the 48-inch force line he main pumping station. As already described, preliminary s, consisting of sand catchers and bar screens, are located at imping stations.

n the force main the sewage enters the distributing conduits lead to the 22 Imhoff tanks. These are of three different due to structural requirements in rebuilding them out of the l septic tanks. The effluent from these tanks passes to a e tank from which it is applied to the trickling filters by a perated dosing mechanism. A float indicates the height of wage in the storage well. At a certain elevation in this well, tes to the filters are opened by hand. Dosing is continued e level has dropped to an established point, and the gates are losed.

trickling filters are in the shape of equilateral triangles laid plan of a hexagon with the control house at the center. Only f the six triangular units have been constructed. Each covers a of 2½ acres, divided into two filters of 1¼ acres each. The ution system is laid on the bottom with risers to the nozzles. ollecting system consists of half tile laid on sloping bottoms. ltering material is 1 to 3 inch stone laid to an average depth feet.

effluent from the trickling filters is carried in a 66-inch circular it directly to the river.

re are in place, as part of the original plant, two secondary entation tanks which were designed to receive the effluent the trickling filters. These, however, are now regularly by- l.

sludge-drying beds are adjacent to the Imhoff tanks; their however, is only one-third to one-quarter large enough. The is shoveled into cars run on tracks down the center of each When filled the cars are hauled by a gasoline locomotive up vee, where they are dumped on the slope.

quate laboratory and office facilities are provided on the l floor of the filter-control house. The supervision of the is under a competent chemist, with a regular personnel con-

TABLE No. 29.—*Costs of construction of the Columbus (Ohio) sewage-treatment*

Item	Original costs, 1907–8	Modification costs, 1908–1920	T
Sewage treatment works	$505, 850	$252, 844	
Main sewage pumping station	272, 550	39, 687	
East side sewage pumping station	73, 380	8, 935	
Night soil station	1, 741	391	
Experimental investigations	45, 290	----------	
Miscellaneous	346, 400	6, 629	
Engineering	107, 550	----------	
Total	1, 352, 761	308, 486	1

The operating costs for the year 1919 are given in the follo table:

TABLE No. 30.—*Summary of cost of operation of the Columbus (Ohio) s treatment works for the year 1919*

Item	East side pumping station	Main pumping station	Sewage-treatment plant	T
Labor:				
Monthly	----------	$10, 826. 85	$4, 473. 00	$2
Daily	$5, 180. 00	1, 024. 83	5, 933. 14	
Power	5, 824. 07	7, 371. 28	----------	1
Supplies and equipment	606. 88	1, 736. 24	594. 87	
Miscellaneous	107. 60	155. 66	125. 02	
Maintenance of filters	----------	----------	800. 68	
Interest	----------	----------	----------	6
Sinking fund	----------	----------	----------	3
Total	11, 718. 55	21, 114. 86	11, 926. 71	13

The average daily volume of sewage treated during 1919 16.8 m. g., and the treatment plant was operated 227 days. D this year, however, the total flow of sewage was not pumped t treatment plant. The data for 1920 giving 21.2 m. g. d. treate much more correct figure for use in computing unit costs. this figure with the 1919 operating cost data, the cost of treat alone was $2.48 per m. g. d., and the total cost of disposal incl pumping, night-soil disposal, and interest and sinking fund $28.86 per m. g.

VI. FITCHBURG, MASS.

The engineering survey of the sewage-treatment plant at F burg, Mass., was made June 29 to July 3, 1920. The labor studies followed about six weeks later, September 15 to 25.

Fitchburg is an industrial city of 41,000 population (1920 cen located in the north-central part of Massachusetts on the branch of the Nashua River. The principal industries are the n facture of textiles and paper goods. In addition there are impo foundries, plants for the production of iron and steel goods, large railroad shops.

sewerage system is a combination of the combined and separate ns. The sewers existent at the time when definite steps were aken toward a treatment plant were of the combined type. 1911 all new construction has been made with the aim of g as complete a separation of sanitary from storm sewage as ible. In addition some separation has been made in the sewers at before 1911, but entire separation is still far from being plished. In an article on the Fitchburg sewage-treatment plant June 7, 1913, issue of the Engineering Record the following nent is made:

> Eddy and Mr. Hartwell find that there are reasonable grounds for ning the desirability of making a complete separation of sewage from water.

accurate data are available as to infiltration or leakage. It was d that this was not excessive. However, the following quota- rom the Engineering Record of June 7, 1913, discussing the s of design considered for the Fitchburg sewerage system and e-treatment plant would indicate an amount of leakage of lerable volume:

> isions has been made for an ultimate maximum rate of leakage of 1,960 per acre per day, which is equivalent to 74,000 gallons per day per mile r assuming the tributary area to be completely sewered.

al topography allows ample grades in almost all instances. range on an average from 1 to 20 per cent with a minimum of er cent. Flushing is done entirely by hose and only when tion indicates it is needed.

on most combined systems, overflows are provided at a number ces to take care of excessive storm flows. These overflows or tors in Fitchburg are arranged to operate at three to four the normal dry weather flow. In addition there is a by-pass head of the main inverted siphon under the river near the treat- plant. It is possible thus to discharge the siphon directly into ver.

total mileage of sewers of various types and sizes was not tely known. From the Thirteenth Semiannual Report of the e Disposal Commission, the following sewers are listed as in December 1, 1916:

BRICK AND CONCRETE SEWERS

Size	Length	Size	L
	Feet		
14 by 21 inches	1,590	36 by 54 inches	
16 by 24 inches	285	24 inches	
18 by 27 inches	3,775	27 inches	
20 by 30 inches	4,293	36 inches	
22 by 33 inches	710	45 inches	
26 by 39 inches	4,710	48 inches	
28 by 42 inches	1,555		
30 by 45 inches	490	Total (7.81 miles)	
32 by 48 inches	4,150		

PIPE SEWER

6 inches	295	18 inches	
8 inches	41,844	20 inches	
10 inches	65,049	24 inches	
12 inches	81,856	30 inches	
15 inches	22,869	12 by 18 inches	
16 inches	3,020	15 by 18 inches	

The total of the two types is 54.26 miles. Since that date (D
ber 1, 1916) 3.12 miles have been constructed up to December 1,
giving a total of 57.38 miles of sanitary and combined sewer
greater part of which are combined.

There are no records of the number of connections to the s
Mr. David A. Hartwell, commissioner of public works, estimate
the total contributing population was 37,000 to 38,000.

In physical appearance and odor, the sewage is received
treatment plant in a fresh condition. However, the analyses
on this survey showed that dissolved oxygen was present in
out of 11 samples. It is normally a dark gray in color, exce
Mondays, when it becomes a light gray. From time to time
it is distinctly reddish. This color was attributed by Mr. Allen,
ist in charge, to paper-mill wastes. He stated that the color p
ated all the sewage in the tanks and that a light reddish-yellow
was formed on the surface. The filters, however, effect a co
removal.

Paper-mill wastes are also evidenced at the pumping station
the South Fitchburg sewage is forced into the siphon to the
Here the screenings contained, in addition to solids normally p
in sewage, slimy masses, which appeared to be paper stock. T
color was not noticeable on the days of inspection. The pape
from which this waste is supposed to originate has installed a
mentation tank as a treatment preliminary to discharge int
sewers, but an inspection of this tank, taken in connection wi
screenings as described above, indicated either by-passing o
indifferent operation of the tank.[8]

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[8] Since the survey David A. Hartwell, commissioner of public works, has reported that this p
waste goes direct to the river.

In addition to this paper mill, a worsted mill discharges the waste from the scouring of 15 to 20 tons of wool per week. This waste is allowed to settle before discharging into the sewers under an agreement covering the maximum allowable flow during any one hour. The total flow is thus distributed to insure adequate dilution at all times.

On the whole, it is doubtful whether the industrial wastes are of such character or of sufficient volume to seriously affect the operation of the treatment plant.

More real difficulty is experienced with grit from the combined sewers. An effort is made to remove this in grit chambers through which the combined sewage is passed before entering the siphon to the plant, but it is found that a considerable amount is carried through these chambers to the plant, where it deposits in the sludge compartment of the Imhoff tanks.

During the year December, 1918, to December, 1919, an average of 3.351 m. g. d. was treated. The variation from the average is quite large. It was stated that the flow at times, though rarely, dropped to a rate as low as 0.5 m. g. d., while during storms it rose to a rate of 10 m. g. d. These extremes represent those received at the treatment plant. The siphon to the plant is capable of handling 14 m. g. d., but the siphons dosing the filters begin to operate continuously at a 10-m. g. d. rate, and for this reason, when the rate reaches this figure, the blow-off on the siphon to the plant is opened and the excess by-passed to the river.

As early as 1896, the city engineer, Mr. David A. Hartwell, recommended the construction of intercepting sewers and a treatment plant. It was not until 1910, however, that a special legislative act authorized the appointment of a commission to undertake these needed improvements. Mr. Hartwell, formerly city engineer and now commissioner of public works, was chief engineer and superintendent of this commission and Mr. Harrison P. Eddy, of Boston, consulting engineer. Early in 1915 the intercepting sewers were constructed and all devices of the treatment plant were in operation. Practically no material changes or modifications have been made subsequent to that date.

Because of local topography the sewage is taken to the plant through a 30-inch inverted siphon, about 1 mile long. Previous to entering this siphon the sewage from the main part of the city is passed through a grit chamber. This chamber, located about one-third mile ahead of the siphon, is divided into two compartments, so that one can be cleaned while the other is in operation.

At the entrance to the siphon there is a coarse bar screen with 1⅝-inch openings.

The sewage from South Fitchburg, from what is known low-level system, is pumped into the siphon about one-third o ahead of the treatment plant. At the pumping station th small sump intended to act as a grit chamber and a bar scre ¾-inch clear openings.

The siphon discharges at the treatment plant through a 3 inch recording Venturi meter. From this it enters five Imho under the siphon head through sluice-gate-controlled orifices. tanks have three sedimentation chambers of the reversible-flo

The tanks discharge into two siphon chambers containing siphons automatically controlled to produce alternating dis They discharge onto 2 acres of trickling filters through W nozzles.

The filter effluent is subjected to final sedimentation throu vertical radial-flow Dortmund tanks, and thence discharged i north branch of the Nashua River.

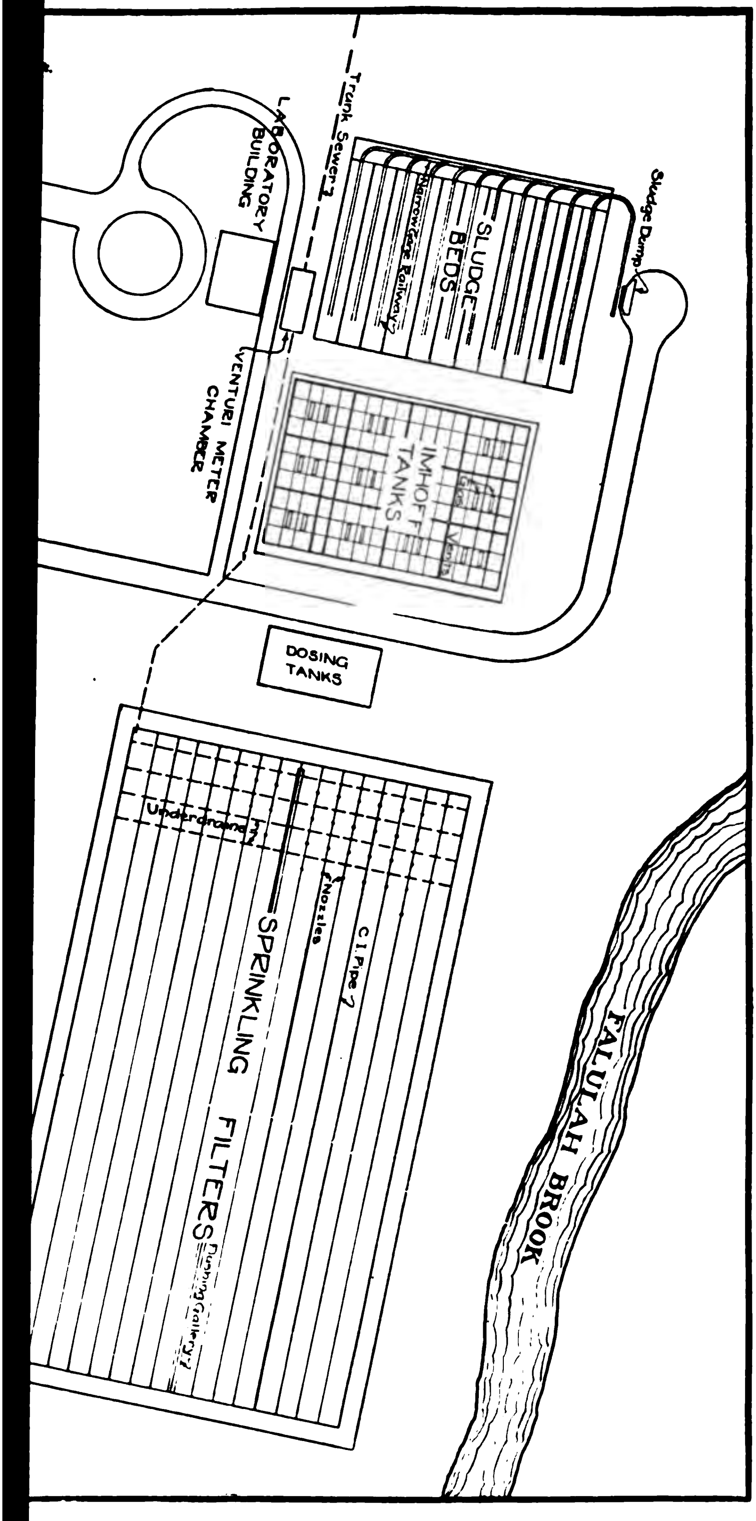
Sludge is dried on 11 sludge beds located adjacent to the tanks, but at an elevation of 3 feet above the water level i tanks, so that it has to be pumped. This is done by an air l addition to the regular sludge beds use is made of some lo adjacent to the plant. The sludge is finally disposed of by f low lands around the plant.

As stated before, the grit chambers can be by-passed. T also a blow-off valve on the 30-inch inverted siphon to th where it crosses the north branch of the Nashua River, just reaching the plant, thus making possible by-passing the entir Within the plant itself by-passes are so arranged that any devices can be eliminated.

Laboratory facilities are very good. They are housed attractive administration building, which also contains th office, the air-lifting machinery for the sludge, storeroo showers and toilet facilities for the men.

Operation is directed by the chemist in charge, who has und a foreman and one laborer during the winter, but four laborers the summer. In addition, there are two watchmen.

The plant as a whole is unusually well kept up. The grou attractively parked and planted, and, what is of more impo properly maintained.


LABORATORY BUILDING
Trunk Sewer
SLUDGE BEDS
Narrow Gage Railway
Sludge Dump
VENTURI METER CHAMBER
IMHOFF TANKS
Gas Vents
DOSING TANKS
Underdrains
Nozzles
C.I. Pipe
SPRINKLING FILTERS
Dosing Gallery
FALULAH BROOK

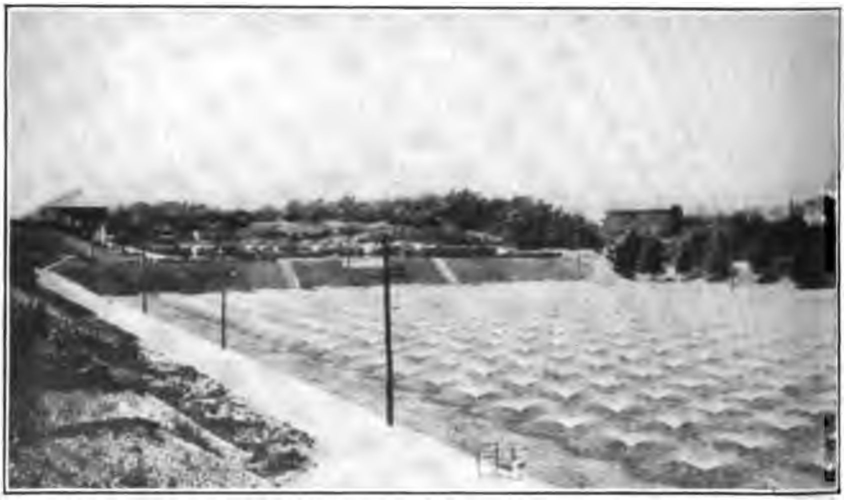


FIG. 11.—TRICKLING FILTERS, WITH IMHOFF TANKS IN THE BACKGROUND, AT FITCHBURG, MASS.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 31.—*Results of chemical analyses at the Fitchburg (Mass.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter					Settleable solids, 2 hours, c. c. per liter [1]				Oxygen consumed 30′ in boiling water				Alkalinity as CaCO₃ by M. O.				24-hour Ether-soluble matter comp. raw	Chlorine as chlorides			
	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw supernatant	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank		Raw.	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank
Sept. 15	......	......	......	......	......	2.5	Tr.	Tr.	Tr.	64	45	19	19	104	112	4	8	82	85	85	85	85
16	240	62	58	30	50	2.5	Tr.	Tr.	Tr.	61	36	20	14	100	108	12	8	56	70	70	70	70
17	300	64	52	40	58	2.5	Tr.	Tr.	Tr.	62	28	19	16	78	100	2	4	67	90	80	80	80
18	344	62	42	38	68	3.2	Tr.	Tr.	Tr.	73	40	20	16	100	94	2	4	54	75	70	70	70
19	280	64	42	54	58	2.5	Tr.	Tr.	Tr.	66	36	14	14	92	84	4	6	72	70	70	70	70
20	180	42	36	36	48	2.5	Tr.	Tr.	Tr.	60	33	15	13	104	104	2	2	50	60	60	65	65
21	336	62	44	38	62	3.0	Tr.	Tr.	Tr.	42	21	19	19	102	98	16	16	72	82	85	88	85
22	340	58	50	42	56	2.7	Tr.	Tr.	Tr.	74	46	24	22	96	102	17	21	64	50	55	55	60
23	324	70	60	46	50	3.0	Tr.	Tr.	Tr.	57	32	17	16	108	102	11	14	58	55	55	62	65
24	288	80	66	54	56	3.0	Tr.	Tr.	Tr.	64	36	20	17	104	100	12	13	62	65	65	65	65
25	340	68	72	46	50	3.0	Tr.	Tr.	Tr.	61	32	17	14	80	84	5	5	58	72	80	75	75
Average	297	63	52	42	56	2.7	Tr.	Tr.	Tr.	65	37	19	16	97	99	7.9	9.1	63	70	70	71	72

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20°± C.								Dissolved oxygen			Hours to reduce M. B. at 20°± C.				Nitrogen as nitrates	
	Raw		Effluent Imhoff tank		Effluent trickling filter		Effluent secondary sedimentation tank		Raw.	Effluent trickling filter.	Effluent secondary sedimentation tank.	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Effluent trickling filter.	Effluent secondary sedimentation tank.
												Per cent concentration					
	1-day	5-day	1-day	5-day	1-day	5-day	1-day	5-day				10	20	100	100		
Sept. 15..	80	156	64	80	7	13	6	14	0.0	7.5	7.7	96	[2] 120	240+	240+	8.8	12.0
16..	56	112	44	84	4	14	4	12	.0	6.8	7.6	96	[2] 240+	240+	240+	6.0	6.4
17..	64	160	40	80	8	22	6	20	.0	8.5	8.9	72	[2] 96	240+	240+	7.6	11.0
18..	64	140	48	98	8	20	8	20	.4	9.0	9.1	48	48	240+	240+	7.2	9.2
19..	80	168	52	112	8	20	9	24	1.0	8.4	9.0	48	48	216+	216+	6.0	5.6
20..	116	160	50	98	8	14	7	14	1.5	8.5	9.0	48	48	192+	192+	7.2	7.6
21..	84	164	52	104	11	28	9	26	.8	8.5	8.4	48	24	168+	168+	1.6	1.3
22..	72	152	50	96	10	24	12	29	.0	7.9	7.7	48	48	144+	144+	1.9	1.5
23..	72	160	48	100	8	22	10	24	.0	8.1	8.0	48	24	120+	120+	2.2	3.0
24..	88	176	50	102	14	30	15	30	.0	6.3	5.8	48	24	96+	96+	4.6	3.2
25..	64	152	.38	88	7	18	7	15	.0	6.3	5.8	48	48	72+	72+	4.8	6.4
Average..	76	154	49	96	8.4	20	8.4	21	.33	7.8	7.9	......	......	......	......	5.2	6.1

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[1] Tr. indicates less than 0.01 c. c.

[2] 16 per cent concentration.

The suspended solids content of the raw sewage was the highest of any found during the summer. Other determinations also run well above the average for all plants visited, though the excess above the average is not so marked.

Considering the strength of the raw sewage, the tanks produce a very good effluent. At only one plant visited was the suspended solids content in a primary sedimentation tank effluent as low as at Fitchburg. The oxygen consumed and the 5-day oxygen demand values are above the average determined on the basis of the summer's work, but they are not too high for the filter treatment.

The filter effluent was stable in all samples subjected to the methylene blue test. While the 5-day oxygen demand is above the average for filter effluents, as found during the survey, the dissolved oxygen content is exceeded only at Alliance, where fine intermittent filters follow contact beds. The nitrate and nitrite value is the highest of any filter effluent. The reduction of the alkalinity by filtration is particularly marked. This is discussed in detail in Chapter III. Practically all the filters studied effected some reduction of this constituent, but at no place did they act as such an efficient water-softening plant.

The final effluent, that from the secondary sedimentation tanks, differs little from the filter effluent. The suspended solids are slightly reduced and the nitrate and nitrite content slightly increased. The purpose of the secondary tanks is largely the removal of solids unloaded from the filters. When the filters are not unloading, as was the case when the above-mentioned analyses were made, the secondary tanks effect little change in the character of the filter effluent.

The dilution factor in the receiving body of water is not definitely known. It is subject to wide variations, being locally estimated to range from 3 to 300. If the analyses in the above table are representative of the average summer sewage and plant effluent, there is little danger of its creating nuisances in the receiving stream, even during periods of minimum flow.

The construction costs of the plant are contained in the following table:

TABLE No. 32.—*Costs of construction of the Fitchburg (Mass.) sewage-treatment plant*

Engineering and inspection about	$30,000
Land	25,008
Imhoff tanks	56,123
Trickling filters	136,546
Secondary sedimentation tanks	8,970
Dosing tanks and apparatus	10,662
Venturi meter and chamber	2,942
Sludge beds	3,055
Pump house and pump	2,008

Overflow chamber	$902
Effluent channel	1, 329
Roadways, parking, etc	10, 711
Pipe lines	9, 668
River improvement	5, 123
Bonus to contractor	5, 000
Laboratory building, complete	15, 214
Miscellaneous about	25, 567
Modifications or improvements since installation	2, 000
Total	350, 828

The maintenance costs given below are for the year December, 1918, to December, 1919. They are taken from the 1919 report of the commissioner of public works. Interest, depreciation, and clerical work incident to keeping accounts, etc., are not included. The totals include administration, laboratory, care of grounds, and miscellaneous expenditures, which, not being chargeable to any of the tabulated accounts, are divided pro rata among them all. The costs incident to pumping sewage at the South Fitchburg pumping station are not included. The cost per million gallons is based upon 1,219.9 million gallons of sewage passed through the plant and the cost per capita upon an estimated population of 38,300 contributing to the sewers November 27, 1919.

TABLE No. 33.—*Summary of cost of operation of the Fitchburg (Mass.) sewage-treatment plant for the fiscal year ended November 30, 1919*

Account	Total cost of operation and maintenance	Cost per m. g. treated	Cost per capita served
Grit chambers	$1, 340. 80	$1. 11	$0. 037
Siphon chamber	263. 82	. 22	. 006
Imhoff tanks	5, 222. 20	4. 29	. 139
Sludge beds	1, 026. 60	. 85	. 027
Trickling filters	1, 899. 04	1. 57	. 045
Secondary tanks	1, 843. 61	1. 52	. 049
Total	11, 596. 07	9. 56	. 303

VII. HOUSTON, TEX.

The engineering survey of the sewage-treatment plants at Houston, Tex., was made August 16 to 20, 1920. The laboratory studies followed a little over two months later, October 12 to 26.

Houston is a city of a little over 147,000, located in the southwestern part of Texas. It is a distributing center for a large surrounding territory, and also contains a number of industrial plants relating principally to cotton, oil refining, agricultural pursuits, and shipping.

While there are two sewerage systems, each tributary to a separate treatment plant, separate discussions would involve much needless repetition. In this report, therefore, they are merged, and the points of difference mentioned in the general discussion.

The sewerage system is largely on the separate plan, there being only a small down-town business section, tributary to the north-side treatment plant, served by combined sewers.

The city engineer does not feel that infiltration over the system as a whole is excessive, but considers it about average. However, he stated that some roof drains were illegally connected to the sanitary sewers, and he considers surface leakage through manhole covers the source of considerable storm water in the sewers. In addition, breaks at isolated points frequently admit large volumes of storm water carrying much mud and grit. It is clearly evident, from the sharp rise in flow and the character of the sewage received at the plants during periods of storm, that large volumes of surface and ground water do enter the sanitary sewers. This volume is at times so large and carries so much grit that it is necessary to by-pass the plants.

While much of the sewered territory is flat, every effort is made to attain grades sufficient to give velocities of 2 feet per second. Eight-inch lines, which is the prevailing size, have grades averaging 0.3 to 0.4 per cent. The larger sizes are laid on flatter grades, 36-inch lines having slopes of 0.045 per cent.

Flushing is done largely by a hose connected to a fire hydrant though there are some flush tanks on the system. There is no regular flushing schedule, stoppages being taken care of as they occur.

The mileage of the different-size sewers was not available, nor was it possible to divide the total mileage between the two plants. On January 1, 1920, the total mileage of the city was 170.

It was estimated that a total population of 100,000 or 68 per cent of the entire city was tributary to the sewers at the time of the survey. There are about 14,000 connections to the sewers, giving an average of seven people per connection. It was further estimated that 80 per cent of the contributing population was served by the north-side treatment plant and 20 per cent by the south-side plant.

There are 20 storm overflows on the system and it was estimated that 10 per cent of the flow is by-passed at these points.

On that part of the system tributary to the north-side plant there are three pumping stations. Two of these, one known as the Houston Heights station and the other as the Westmoreland station, located in the northeast and southwest sections of the city, respectively pump to the main or Willow Street station. All three stations are provided with screens, but only one, the Willow Street station, has a grit chamber. After passing through the screens and grit chamber at this station, the sewage is lifted by centrifugal pumps to the concrete gravity line to the north-side treatment plant.

The bulk of the sewage received at the south-side plant is pumped at the south-side pumping station. Here it is passed through a screen with 1-inch clear openings and some of the heavy grit drops in a well provided for this purpose.

The character of the sewage received at both plants depends to a considerable extent upon weather conditions. During dry weather it has the appearance of a typical domestic sewage, apparently fresh after a maximum travel in the sewers of about six hours. It will be noted, however, in the tables of analyses that dissolved oxygen is only occasionally present. During wet, rainy weather the character of the sewage is more nearly that from combined sewers, carrying excessive amounts of mud and grit. At such times it is customary to by-pass the entire flow around the plants.

The only industrial waste of any consequence is oil from power plants and factories which occasionally reached the north-side plant in sufficient quantity to cause considerable interference in the operation of the plant. It is customary to by-pass the entire flow at such times. In addition to this waste, the north-side plant receives the night soil from 12,000 privies, averaging about 1,200 gallons a day.

The average dry-weather flow received at the north-side plant is about 6 m. g. d., with variations of from 3.5 to 9.2 m. g. d. These figures do not include heavy storm flows, the volume of which is not definitely known, but is estimated to run as high as a 20 m. g. d. rate. They are, however, fairly representative of the volume actually treated since the very high storm flows are by-passed.

The average dry-weather flow for the south-side plant is 1½ m. g. d. with variations from 0.9 to 2.3 m. g. d. The general statements in the preceding paragraph relative to storm flows are applicable to this plant also.

The treatment plants were built in 1916 and 1917, and put in operation in 1917. They were designed by Mr. E. E. Sands, city engineer at that time. Some modifications have been made since that date, notably the removal of the iron castings holding the filtros plates, and the cementing of these plates directly to the bottom of the tanks. This work was done in 1920.

Sewage is received at the north side plant in a concrete gravity main. Most of it has, however, been pumped into this gravity main and some has been pumped twice.

At the plant itself the sewage enters the aeration tanks of which there are four in place, but only three are used. These tanks are long and narrow, the length being about 15½ times the width. About one-seventh of the bottom consists of filtros plates. In these tanks the sewage is under constant aeration for its entire length, receiving 1.5 cubic feet of air per gallon of sewage.

From the aeration tank the sewage flows to the sedimentation tanks through a long narrow channel in which aerators are placed at intervals to prevent sedimentation. It enters these tanks through flap gates located near the bottom of the inlet channel. These gates are opened to stand at an angle of 45° and act as downward deflectors. The effluent from these tanks passes to an outlet channel, and thence over a weir to the ship channel or bayou without further treatment.

Sludge settling in the final tanks is raised by air lifts to a reaeration tank of the same design as the sewage aeration tanks, except that it is only about one-half as wide. In this tank the sludge is aerated and carried back to the inlet of the sewage aeration tanks where it is mixed with the incoming sewage entering these tanks.

The flow of sewage through the plant is measured as it passes the final outlet weir by a recording gage. The amount of air is measured by a Pitot tube inserted in a reduced section of 12-inch pipe. All air is screened to reduce clogging of the filtros plates.

Plants of this type require considerably more machinery than any other type of sewage treatment. At Houston the motors, air compressors, pumps, etc., are housed in a substantial attractive brick building.

There are no overflows at the plant, but the entire flow can be by-passed around the plant, and this is done at times of storms when the flow is above the maximum capacity of the plant and when the sewage carries an excessive amount of grit which would settle out in the aeration tank and interfere with operation, or when, as occasionally happens, the sewage is carrying a large amount of oil wastes.

A dewatering plant to dry sludge has been installed, though it is not yet in operation, as it has been impossible to secure a proper conveyor. The sludge is to be pumped from the final tanks of the treatment plant to three large elevated wooden tanks where a short period of sedimentation is allowed. From these it flows by gravity to two ejectors, which force it into two large presses. The cake is dumped into storage bins to be picked up by the conveyor to a rotary dryer. After drying, the large lumps are screened out, ground, and rescreened, all screenings being carried to a storage room by a conveyor. It will be loaded from here into cars or wagons by a loading conveyor. At the time of the survey, sludge was being run to two large artificial lagoons, which had been used for about three years.

Laboratory facilities for both treatment plants are provided at the north-side plant. These consist of an adequately equipped laboratory, in charge of a part-time student chemist, who is to be replaced by a full-time man.

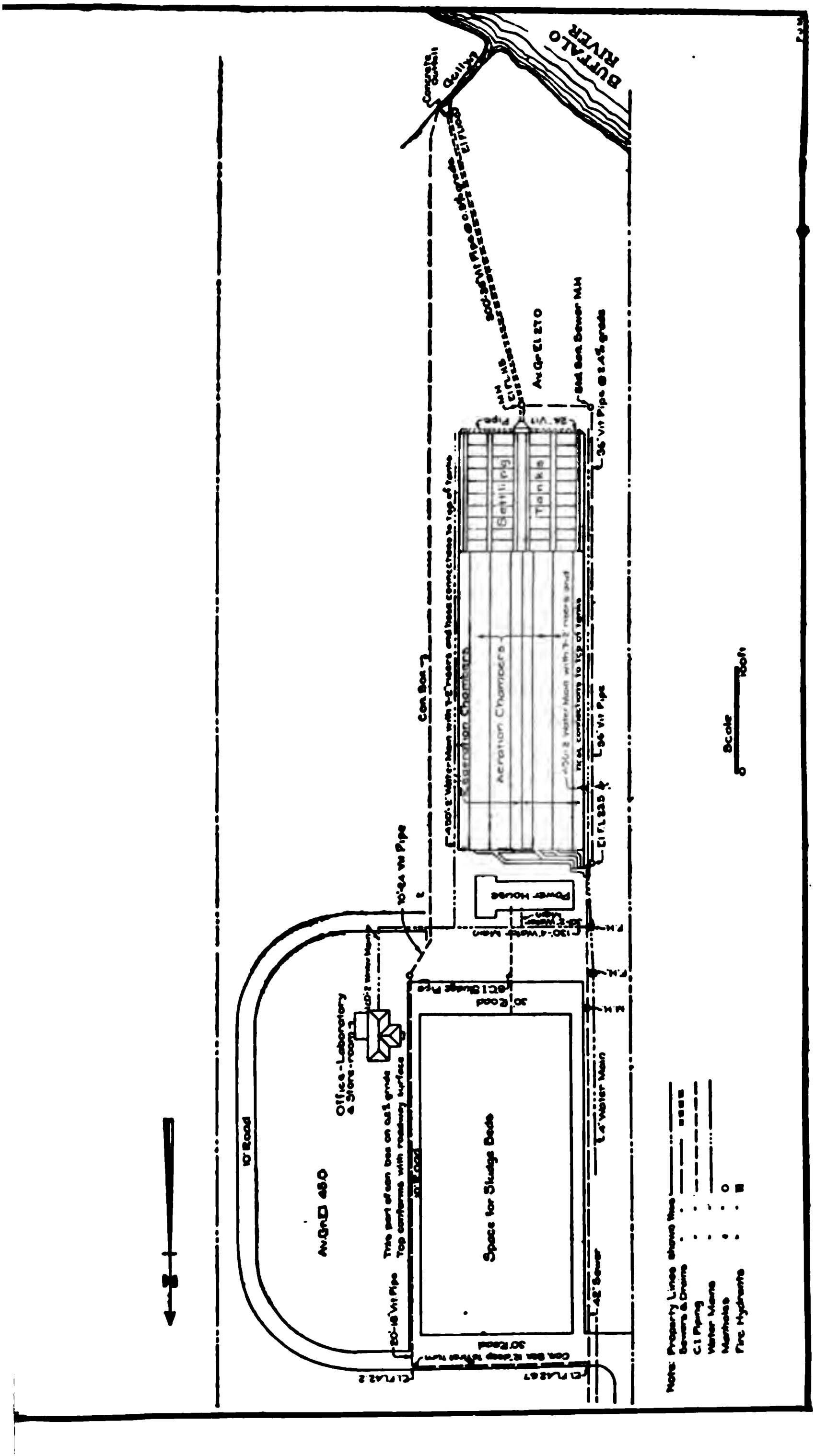


FIG. 12.—General plan of the north-side sewage-treatment plant at Houston, Tex.

The operation of the plant is in the hands of a chief operator, who operates the plant 8 hours and has general supervision over the two operators at the plant the remaining 16 hours. In addition there are three laborers.

Practically no improvements have been made in the grounds surrounding the plant. The treatment devices are concentrated in a small area, located in a basin with the land rising sharply on three sides. It was intimated that some steps toward planting and parking the grounds were being contemplated.

The south side treatment plant is the same in general design and in most of its details as the north-side plant, already described, except that it is just one-half as large. The air used is slightly more than at the north side plant, being 1.7 as against 1.5 cubic feet per gallon.

There is no sludge-dewatering plant provided, and all sludge is pumped to a large lagoon. The future method to be adopted, whether more lagoons or some other means of disposal, is still unsettled. Experience with the dewatering plant at the north side plant and future possible development in sludge treatment will decide this question when the time comes.

The laboratory facilities provided at the north side plant are sufficient to handle both plants, and only an office and tool house has been built at the south side plant.

Operation is in the hands of a chief operator with two assistant operators and one laborer.

At the time of inspection very little attention had been given to improving the grounds around the plant.

The results of the chemical analyses made at the north side plant are contained in the following table:

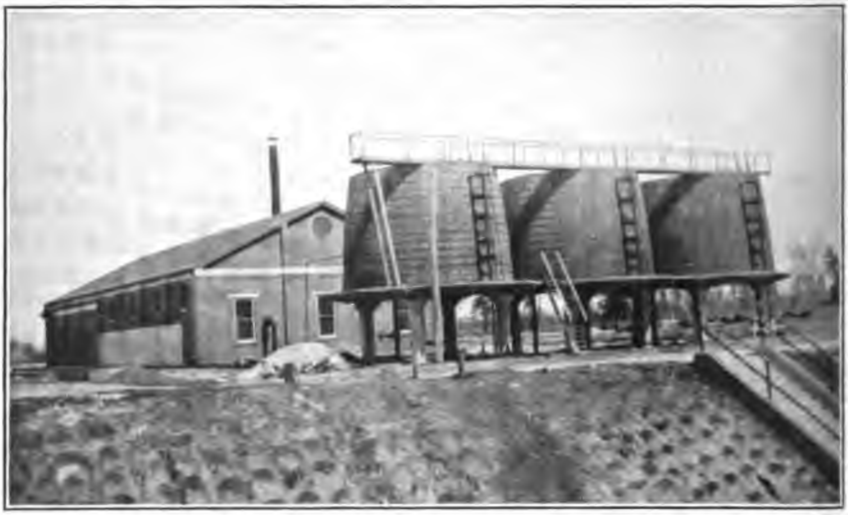


FIG. 13.—SLUDGE DRYING PLANT AT THE NORTH SIDE PLANT AT HOUSTON, TEX.

TABLE No. 34.—*Results of chemical analyses at the Houston, north side sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter			Settleable solids, 2 hours c. c. per liter raw	Oxygen consumed 30′ in boiling water		Alkalinity as $CaCO_3$ by M. O.		Ether soluble matter 24-hour comp. raw	Chlorine as chlorides	
	Raw	Effluent final sedimentation tank	Raw supernatant		Raw	Effluent final sedimentation tank	Raw	Effluent final sedimentation tank		Raw	Effluent final sedimentation tank
Oct. 13	160	14	26	2.0	60	12.0	328	212	38	150	150
14	210	10	46	3.0	59	11.0	272	208	54	165	160
15	284	12	60	4.5	54	11.0	292	204	48	160	160
17	168	5	46	2.0	49	9.4	288	220	37	135	130
18	146	11	42	1.7	30	8.2	288	204	34	125	125
19	206	12	40	2.5	45	11.0	276	212	36	170	145
20	184	17	56	2.5	45	9.6	308	254	44	152	157
21	180	5	36	3.5	48	8.4	300	252	47	150	150
22	346	30	72	2.5	45	9.8	200	248	29	110	140
23	124	17	36	.7	20	11.0	168	128	17	75	110
25	------	60	------	------	------	10.0	------	104	------	------	85
26	194	6	44	3.0	45	10.0	248	128	42	100	100
Average	200	17	46	2.5	45	10.0	270	198	39	136	134

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C				Dissolved oxygen		Hours to reduce M.B. at 20° ± C		Nitrogen as—		
	Raw		Effluent final sedimentation tank		Raw	Effluent final sedimentation tank	Raw	Effluent final sedimentation tank	Ammonia		Nitrates effluent final sedimentation tank
							Per cent concentration		Raw	Effluent final sedimentation tank	
	1-day	5-day	1-day	5-day			10	100			
Oct. 13	56	104	3.4	10.0	0.0	5.7	48	240+	9	2.0	8.8
14	84	160	2.1	6.4	.0	5.4	24	240+	16	2.2	4.8
15	56	140	2.4	5.5	.0	5.8	48	240+	27	2.7	5.2
17	44	100	3.5	12.0	.0	5.3	48	240+	18	10.0	4.8
18	36	84	3.3	7.5	.0	5.2	48	240+	20	5.0	1.2
19	40	96	4.2	24.0	.0	5.0	48	216+	15	4.8	1.0
20	90	160	3.6	13.0	.0	4.3	------	192+	27	7.2	1.4
21	56	128	2.5	12.0	.0	4.6	48	168+	------	------	2.4
22	28	68	5.0	10.0	.0	4.4	------	144+	10	8.0	2.4
23	32	------	------	------	1.7	5.3	------	120+	8	.7	9.6
26	------	------	------	------	------	6.2	------	72+	------	.5	9.6
Average	52	115	3.3	11	.2	5.2	------	------	17	4.3	4.6

With the exception of Baltimore, no raw sewage studied more closely approximated the average obtained from all plants surveyed. The suspended solids are about 15 per cent high, but the other critical constituents, such as settleable solids, oxygen consumed and oxygen demand are unusually close to the average. The dissolved oxygen is rather less than was to be expected from the physical appearance of the sewage and its short travel in the sewers. Only at activated sludge plants was the ammonia-nitrogen determination made. At these plants it is of particular value as indicating the efficiency of the aeration, as measured by the reduction of this constituent.

This plant represents the largest permanent installation of the activated sludge process in this country. Judged by the effluent obtained at this plant, the process is undoubtedly capable of producing a thoroughly satisfactory effluent under actual operating conditions. It compares very favorably with the effluents from trickling filters studied on the survey. The suspended solids are lower than any trickling filter effluent, the reduction in oxygen consumed greater, the 5-day oxygen demand about the same as the properly operating filters, and the nitrates and nitrites well above the average. The effluent from this plant should be readily handled by any body of water capable of receiving the effluent from any type of plant of this capacity.

The results of the chemical analyses made at the south side plant are contained in the following table:

Table No. 35.—*Results of chemical analyses at the Houston south side sewage treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter			Settleable solids, 2 hours c. c. per liter[1]		Oxygen consumed 30′ in boiling water		Alkalinity as $CaCO_3$ by M. O.		Ether soluble matter 24-hour comp., raw	Chlorine as chlorides	
	Raw	Effluent final sedimentation tank	Raw supernatant	Raw	Effluent final sedimentation tank	Raw	Effluent final sedimentation tank	Raw	Effluent final sedimentation tank		Raw	Effluent final sedimentation tank
Oct. 12	......	5	......	Tr.	Tr.	......	6.8	......	196	......	......	107
13	196	5	46	2.0	Tr.	37	4.8	336	208	48	110	110
14	180	7	52	3.0	Tr.	43	6.4	332	220	34	120	120
15	372	6	36	2.5	Tr.	52	6.4	316	200	42	105	105
18	132	14	42	1.0	Tr.	26	7.6	308	208	21	100	107
19	194	3	20	1.5	Tr.	34	6.8	288	216	32	100	105
20	164	12	42	2.1	Tr.	37	6.0	328	220	34	110	110
21	92	1	48	2.5	Tr.	33	6.2	316	248	42	102	107
22	476	6	100	2.0	Tr.	41	6.2	208	224	31	60	100
25	......	14	......	......	......	......	6.8	......	264	......	......	90
Average	226	7.3	48	2.1	Tr.	38	6.4	304	220	36	101	106

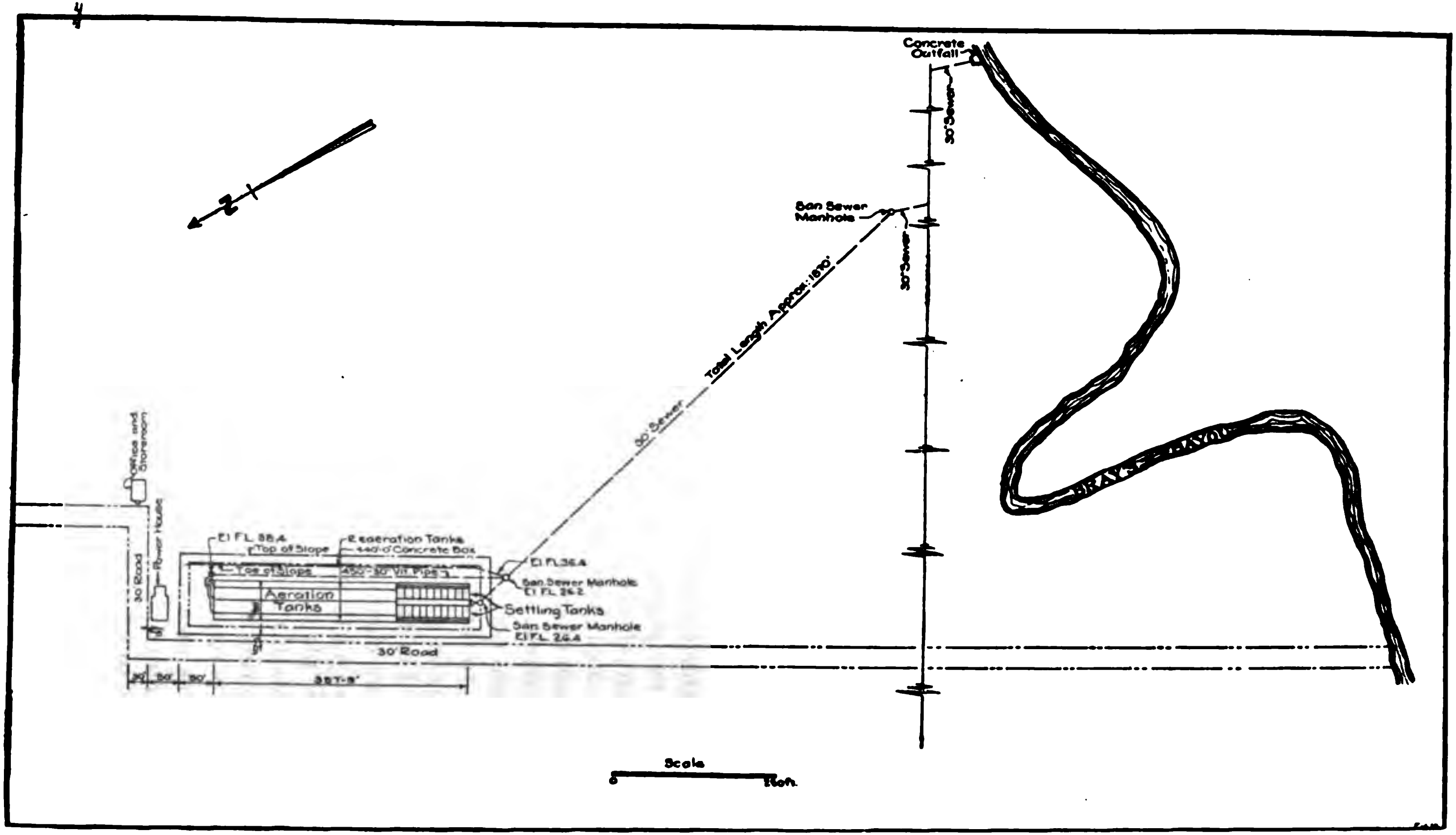
[1] Tr. indicates less than 0.1 c. c.

TABLE No. 35—*Results of chemical analysis at the Houston south-side sewage-treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.				Dissolved oxygen		Hours to reduce M. B. at 20° ± C.		Nitrogen as—		
	Raw		Effluent final sedimentation tank		Raw	Effluent final sedimentation tank	Raw	Effluent final sedimentation tank	Ammonia		Nitrates, effluent final sedimentation tank
							Per cent concentration		Raw	Effluent final sedimentation tank	
	1-day	5-day	1-day	5-day			10	100			
Oct. 12	......	......	2.0	6.0	0.0	7.5	......	240+	......	1.2	8.8
13	52	120	2.3	6.5	.0	7.8	48	240+	22	1.5	9.2
14	60	120	2.4	7.4	.0	7.8	72	240+	18	1.2	7.2
15	48	176	1.8	7.5	.0	8.3	72	240+	15	1.0	6.8
18	12	88	3.0	9.0	2.8	7.5	96	240+	20	2.0	.6
19	20	64	2.2	7.5	1.8	7.5	72	216+	15	1.0	4.2
20	40	112	2.5	8.0	.0	6.9	48	192+	24	3.6	7.2
21	48	104	2.3	7.5	.0	7.4	48	168+	......	......	4.0
22	28	......	2.5	7.0	2.4	6.9	......	144+	10	3.6	4.0
26	......	......	......	......	......	7.1	......	72+	......	.6	8.4
Average	38	112	2.3	7.4	.8	7.4	......	......	18	1.7	6.0

The raw sewage at this plant contained a higher suspended solid content than that at the north side plant, but in other respects it was weaker, though not enough so to affect a comparison of the efficiency of the two plants. In such a comparison the effluent from the south side plant shows up better than that from the north side plant. It should be noted, however, that 1.7 cubic feet of air was used at this plant per gallon of sewage, while at the north side plant the amount was 1.5. Moreover, it is not believed that the conditions at the north side plant were normal during the period covered by the analyses. Just previous to this period there had been some trouble in maintaining the sludge in proper condition, due, it was stated, to excessive amounts of oil in the sewage, and a new supply of sludge was being built up. The chemist making the studies felt that under normal conditions the north side plant produces fully as good an effluent as the south side plant.

Taken by itself the effluent from the south side plant is among the best found during the survey, containing within itself more dissolved oxygen than is required to satisfy the 5-day demand. The efficiency of aeration, as measured by the reduction of ammonia nitrogen, is particularly noteworthy, this constituent being reduced over 90 per cent, from 18 to 1.7 parts per million.


Concrete Outfall
30" Sewer
San Sewer Manhole
30" Sewer
Total Length Approx. 1870'
30" Sewer
BRAYS BAYOU
N
El FL 38.4
Top of Slope
Toe of Slope
Reaeration Tanks
440-0" Concrete Box
450'-30" Vit Pipe
Aeration Tanks
El FL 36.4
San Sewer Manhole
El FL 26.2
Settling Tanks
San Sewer Manhole
El FL 26.4
30' Road
30' Road
Power House
Office and Storeroom
30'
50'
50'
357'-9"
Scale
0
150ft.

The construction costs of the two Houston plants are contained in the following table:

TABLE No. 36.—*Construction costs of the north side and south side sewage-treatment plants at Houston, Tex.*

Item	North side plant	South side plant
Excavation	$25, 822	$5, 488
Tank buildings, etc	[1] 194, 405	87, 789
Air and power equipment	17, 827	7, 650
Filtros plates	6, 439	2, 800
Engineering	10, 095	7, 656
Miscellaneous	83	[2] 3, 680
Resetting filtros plates—net	2, 700	250
Total	257, 371	115, 313

[1] Does not include the $68,000 sludge drying plant.

[2] Includes water-supply system.

The operating cost for the year 1919 is contained in the following table. This table is arranged to give the cost per million gallons, treated on the basis of average treatment of 6 m. g. d. for the north side plant and 1.5 m. g. d. for the south side plant. It is noticed that depreciation and interest on the investment are not included.

TABLE No. 37.—*Operating costs per million gallons of the north side and south side sewage-treatment plants at Houston, Tex., for the year 1919*

Item	North side plant	South side plant
Power at 1 cent per kilowatt hour	$9. 000	$8. 000
Chief operator	. 945	3. 560
Two operators	1. 445	5. 780
Labor	1. 875	2. 667
Chemist, two-thirds for north, one-third for south	. 600	. 300
Supplies	. 833	. 890
Total	14. 698	21. 197

In considering these figures, allowance must be made for the fact that neither plant is operating at its capacity. Even allowing for this, however, the costs are well above the average for other types of plants of equal capacity.

VIII. LEXINGTON, KY.

The engineering survey of the sewage-treatment plant at Lexington, Ky., was made August 4 to 7, 1920. The laboratory studies followed immediately, August 11 to 21.

Lexington is a city of 41,500 population (1920 census), located in the central part of Kentucky. It is the center of a large, wealthy agricultural territory, and one of the important tobacco markets of the country. There are comparatively few industrial plants, none producing wastes of such character and volume as to affect the operation of a sewage-treatment plant.

The sewerage system is of the separate type. It was stated, however, that some roof drains are connected to the sanitary sewers, and that the storm sewers receive a small amount of strictly sanitary sewage. The exact extent of this deviation from the general policy of separation is not known.

Infiltration is well above the average, many of the sewers having been laid in water. Heavy storms always produce a marked increase in flow at the treatment plant, amounting to five to six times the dry-weather flow.

The grades are sufficient to insure a self-cleaning velocity of 2 feet per second when the sewers are flowing half full. Lateral sewers are laid on a 0.6 per cent average grade, the main or trunk sewers about 0.3 per cent, and the 39-inch outfall to the plant on a 0.13 per cent.

Flushing or cleaning is done almost entirely by flush tanks, of which there are 140 on the system. Hose flushing is resorted to only in case of stoppages.

The following list of the various size pipes composing the sewerage system was obtained from the city engineer:

	Linear feet		Linear feet
5-inch (house connections)	75,000	18-inch	4,000
8-inch	185,000	20-inch	4,000
10-inch	6,000	24-inch	11,000
12-inch	3,000	39-inch	5,300
15-inch	18,000		

With the exception of the 39 inch, which is segmental block, all of the above are vitrified tile. The total mileage represented in the table is approximately 40.

It was estimated that there were 4,500 house connections to the sanitary sewers, through which sewage is received from 28,000 people. This figures 6.2 persons per connection.

There are two overflows on the sanitary system. These, it was stated, operate about five times a year, so that but very little sanitary sewage fails to reach the treatment plant because of these overflows.

The raw sewage received at the treatment plant has the physical appearance of a normal fresh sanitary or domestic sewage. While it was devoid of oxygen on seven out of ten days on which analyses were made, the travel in the sewers is relatively short, and no indication of advanced septic action was visible.

Industrial wastes, it was stated, are seldom detectable, though occasionally a small amount of slaughterhouse waste is observed. From a treatment standpoint, the industrial waste entering the sewers may be neglected.

The average dry-weather flow was estimated at 2.5 m. g. d. This figure may be considered fairly accurate as it was obtained by counting, for a definite period on several different days, the number of times the siphon tanks discharged to the filters. No regular flow records are, however, kept. From the average of 2.5 m. g. d. the variations in dry-weather flow run from 1.0 to 3.5 m. g. d. At times when prolonged heavy rains cause large increases in the infiltration factor, the flow may reach a 14 m. g. d. rate, but it is customary to by-pass around the plant all in excess of a 5 m. g. d. rate.

The average water consumption throughout the year is 4 m. g. d. This includes industrial users, some of which, such as railroads, do not contribute sewage in proportion to their water consumption. Deducting industrial consumption, the domestic per capita consumption is about 60 gallons per day.

The treatment plant was designed by the Soloman-Norcross Co., consulting engineers of Atlanta, Ga. It was built in 1918, and was, herefore, in operation three years at the time of this survey. There have been no material enlargements or modifications made since the plant was put in operation.

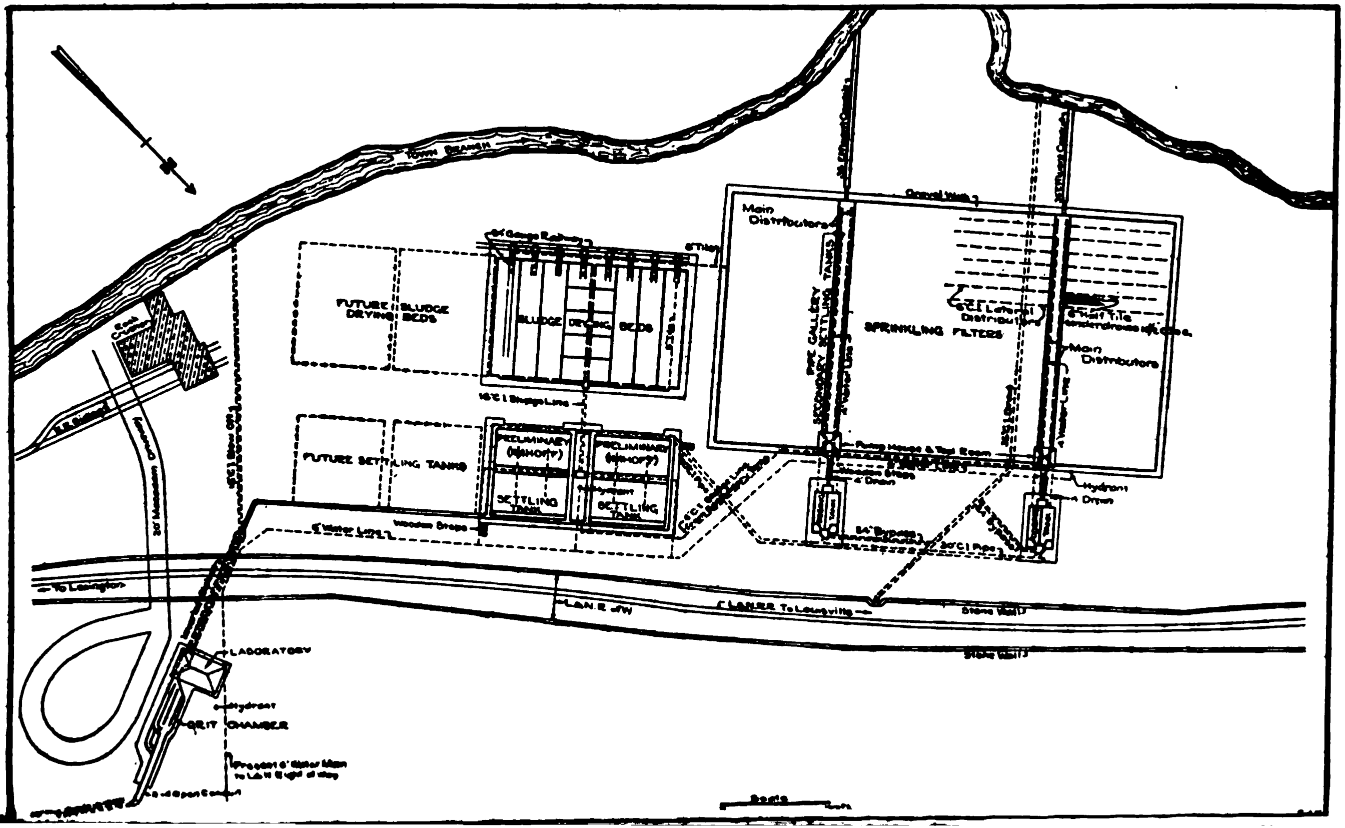
The treatment plant is located west of, and about 2½ miles from he center of the city, and about a mile from the west boundary ine. The sewage enters the plant through a segmental tile block ewer. It passes through an inclined coarse bar screen just before ntering the grit chambers of which there are three. Two of these re, as a matter of general routine, operated in parallel with the hird lying in reserve. From the grit chambers the sewage passes hrough an inverted siphon under the Louisville & Nashville Raiload tracks to the inlet conduit of the Imhoff tanks.

These are four reversible-flow, double-channel, medium deep tanks. he effluent from them is applied through two automatic siphon dosg tanks onto four trickling filter units. The individual underdrains f the filters discharge direct into the secondary sedimentation tanks. hese are two long, narrow tanks, each located between and serving wo filter units. The two outlet conduits from these tanks lead irect to Town Branch, the receiving stream.

There are two sludge beds, each divided into four units, with an rea of 210 square feet each. About 50 per cent of the dried sludge hauled away by farmers.

By-passes are so located that the whole plant or any single unit an be cut out. In addition there is an emergency overflow just head of the bar screens.

A laboratory and administration building, included in the original esign, is available, but has never been equipped for laboratory work. nalyses, of which eight sets were made in 1919, are made by a art-time chemist who also makes periodical inspections of the plant.


TOWN BRANCH
Main Distributors
PIPE GALLERY
SECONDARY SETTLING TANKS
SPRINKLING FILTERS
C.I. Lateral Distributors
6" Half Tile Underdrains
Main Distributors
Gravel Walk
Pump House & Tool Room
Hydrant
Drain
24" Bypass
30" C.I. Pipe
6" Tiles
FUTURE SLUDGE DRYING BEDS
SLUDGE DRYING BEDS
16" C.I. Sludge Line
PRELIMINARY (IMHOFF) SETTLING TANK
PRELIMINARY (IMHOFF) SETTLING TANK
FUTURE SETTLING TANKS
Wooden Steps
Water Line
30' Macadam Drive
→ To Lexington
L.&N.R. R/W
L.&N.R.R. To Louisville →
Stone Wall
Stone Wall
LABORATORY
Hydrant
GRIT CHAMBER
Present 6" Water Main to L.&N. Right of Way
Scale
Feet

The plant is operated by a superintendent who lives at the plant. There is a watchman on duty at night and, by arrangement with the county in which the plant is located, four chain-gang laborers are available as needed.

Up to the time of the survey (August, 1920), very little work had been done around the grounds. The plant is comparatively new, and work has been held up by the war. The land is very poor but is being built up by sludge from the plant. Plans are well formulated for parking and improving the grounds. When these have been carried out the plant, as a whole, should present a very attractive appearance.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 38.—*Results of chemical analyses at the Lexington (Ky.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a.m.—	Suspended matter					Settleable solids, 2 hours c. c. per liter [1]				Oxygen consumed 30′ in boiling water				Alkalinity as CaCO$_3$ by M. O.				Ether soluble matter 24-hour comp., raw	Chlorine as chlorides			
	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw supernatant	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank		Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank
Aug. 11	208	142	111	75	20	1.8	Tr.	Tr.	Tr.	38	24	....	9	136	154	....	....	40	75	85	90	87
12	193	45	25	50	8	2.2	Tr.	Tr.	Tr.	20	11	3	4	124	124	....	83	50	82	85	85	85
13	176	47	29	44	....	2.2	Tr.	Tr.	Tr.	23	14	6	7	206	186	152	156	61	117	85	85	78
14	....	....	....	....	....	1.5	Tr.	Tr.	Tr.	22	18	....	8	222	....	....	166	50	78	78	....	78
15	145	42	20	62	....	1.5	Tr.	Tr.	Tr.	26	24	....	6	211	244	....	155	62	99	99	....	99
16	116	68	....	68	....	2.1	Tr.	Tr.	Tr.	39	21	13	11	196	208	....	132	46	57	85	....	82
17	....	....	....	....	....	2.8	0.3	Tr.	Tr.	38	21	7	4	216	160	172	132	98	85	99	107	86
18	96	40	27	33	....	1.7	Tr.	Tr.	Tr.	36	32	22	8	220	244	156	158	65	117	96	99	71
19	231	60	25	52	....	6.7	Tr.	Tr.	Tr.	33	31	14	15	228	214	144	134	50	85	107	99	92
20	208	108	38	40	....	1.9	Tr.	Tr.	Tr.	42	25	12	26	206	208	140	140	54	92	92	92	92
21	128	53	43	18	....	1.8	Tr.	Tr.	Tr.	38	24	14	10	196	200	150	112	57	89	107	99	99
Average	166	67	40	48	14	2.4	Tr.	Tr.	Tr.	32	22	11	9.8	196	194	152	137	58	89	92	94	86

TABLE No. 38.—*Results of chemical analysis at the Lexington (Ky.) sewage-treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.						Dissolved oxygen		Hours to reduce M. B. at 20° ± C.			
	Raw		Effluent Imhoff tank		Effluent secondary sedimentation tank		Raw	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank
	1-day	5-day	1-day	5-day	1-day	5-day			Per cent concentration			
									10	10	100	100
Aug. 11	36	126	24	88	2	16	0.0	5.2	46	70	144+	144+
12	48	136	40	96	2	14	.0	5.2	47	47	144+	144+
13	72	164	24	64	6	16	.0	5.4	48	50	120+	120+
14	44	88	44	72	6	18	.3	4.0	72	72	120+	120+
15	64	136	40	.88	1	16	.0	6.2	72	72	120+	120+
16	56	112	24	60	3	12	.6	5.1	94	94	120+	120+
17	64	136	44	84	6	19	.1	5.8	48	48	144+	144+
18	72	124	56	112	5	13	.0	4.1	46	46	120+	120+
19	140	272	-------	120	5	22	.0	4.4	96+	96+	96+	96+
20	52	-------	-------	-------	-------	-------	.0	7.2	71	71	72+	72+
21	-------	-------	-------	-------	-------	-------	-------	-------	47	48+	48+	48+
Average	65	144	37	87	4.0	16	.1	5.2	-------	-------	-------	-------

[1] Tr. indicates less than 0.1 c. c.

With the exception of the oxygen demand, the raw sewage is slightly weaker than the average found on the survey. Though dissolved oxygen is only occasionally present, and then only in small amounts, there is no indication in the physical appearance and odor to indicate that the sewage is septic. In this instance, and in several others encountered during the survey, it is not believed that the dissolved oxygen determination is a true indication of the character of the sewage as sampled. The dissolved oxygen determination was made more as an adjunct to the oxygen demand determination than as a separate determination. It was made, therefore, on the 24-hour composites. While the samples were kept on ice during the entire collection period, it is very possible that a small dissolved oxygen content could be used up during this storage.

The Imhoff tanks, by effecting a removal of 60 per cent of the suspended solids, 30 per cent of the oxygen consumed, and 40 per cent of the oxygen demand constituents, satisfactorily prepared the sewage for the oxidizing action of the trickling filters.

The effluents from the trickling filters and that from the secondary sedimentation tanks both showed a very high stability based upon the methylene blue test. Dissolved oxygen was present in comparatively large amounts in the secondary sedimentation tank effluent. The suspended solids from these tanks were higher than from the filters, but this is of no significance, since the solids in the effluent depend upon the frequency with which sludge is removed from these tanks.

Town Branch, the receiving body of water, is not sufficiently large to afford a very high dilution of the plant effluent it receives. In addition, above the treatment plant an oil refinery discharges a small amount of waste, so that at point of entrance the sewage had on the day of inspection a better physical appearance than the water in the stream. Even under these unfavorable conditions the stream is apparently capable of caring for the sewage without creating any nuisance. Even should trouble arise, the oil waste should be eliminated before placing blame on the sewage-treatment plant, which seems to be producing an effluent satisfactory for disposal by the available dilution.

The initial cost involved in putting the treatment plant in operation was $241,100. Of this $39,500 was expended in the construction of the outfall sewer from the city sewer system to the treatment plant, leaving $211,600 for the treatment plant proper. As the bids were submitted and payment made on a unit basis with but few lump-sum items, it is not possible to separate the total cost into the various treatment devices.

Since the original installation $5,062 have been expended in modifications, improvements, enlargements, or additional work. A little over $4,000 of this was spent on the grounds for grading, roadways, and walks.

For maintenance and operation $6,600 was appropriated for 1920. Out of this the superintendent in charge of operation receives $1,800 and the chemist, part time, $900. The only other regular employee is the night watchman. From time to time special labor is employed as needed. It should be noted that the common laborers, of which there are regularly two, are not entered as an expense against the plant. These two laborers, and occasionally two more, are city prisoners farmed out to the county authorities under an agreement by which the sewage-treatment plant is entitled to four laborers. Because of this arrangement the appropriation of $6,600 is too low to be used in comparisons with operating cost data at other plants.

By the accounting system used by the city interest on bonds issued for construction of the outfall sewer and treatment plant is not charged back annually as against these improvements. Nor is any allowance made for depreciation. All clerical work in connection with the plant is done in the engineer's and auditor's office by their departmental clerks, and no charge is made against the plant for this service.

IX. Reading, Pa.

The engineering survey of the sewage-treatment plant at Reading, Pa., was made July 14 to 17, 1920. The laboratory studies followed about a month later, August 6 to 16.

Reading is a city of 114,000 population located in the southeastern part of Pennsylvania on the Schuylkill River. It is an industrial center with a wide range of industries, including soap works, dye works, tanneries, paper mills, hat factories, breweries, and metal-work plants.

The sewerage system of Reading is built on the separate plan. There are no definite data on the amount of infiltration and leakage of storm and ground water into the sanitary sewers, but it is locally considered to be an average amount for sewers of this type. There are no storm overflows on the system and the variation in pumpage does not indicate any excessive infiltration.

All sewers lead to the pumping station where the sewage is screened, as described in detail in Appendix I, and is pumped by 2 R. D. Wood horizontal centrifugal pumps of 6 and 8 m. g. d. capacity, direct connected to 100 and 150 horsepower Westinghouse motors. The gradients are stated to be very satisfactory, averaging about 0.75 per cent.

Cleaning is done entirely oy hose flushing from fire hydrants. There is no regular schedule, and sewers are flushed whenever there is evidence of their needing it.

The total mileage of sewers is 150, of which about 70 are house connections. The following table divides this into the various sizes. Note is made that the 5-inch lines are all house connections.

	Linear feet		Linear feet
5-inch	314, 248	15-inch	9, 255
6-inch	854	18-inch	5, 840
8-inch	9, 665	20-inch	1, 186
10-inch	402, 467	24-inch	5, 256
12-inch	41, 762	54-inch	2, 862

The city plumbing inspector estimated a total of 11,889 connections to the sewers, and the city officials estimated the contributing population to be 60,000.

The raw sewage is primarily a domestic sewage from separate sewers into which an average amount of infiltration enters. Its character is also altered more or less by industrial wastes. As the maximum travel in the sewers to the pumping station is 2 to 2½ miles, and the time of passage from the pumps to the septic tank at the treatment plant is 40 minutes, the sewage is received at this plant in a fresh condition.

Quite a variety of industrial wastes is tributary to the sewers. Dye waters often change the normal dirty brown color to a dark blue or red or other colors. Felt from a hat factory and some hair from a mattress plant were noticeable in the deposit in the trickling filters. There are also discharged into the sewers tanning wastes, spent metal, pickling liquors, and laundry wastes. One very troublesome waste, the source of which is not known, is received at the pumping station at irregular intervals. It consists of large quantities of a heavy dark grease. At times as much as 3 barrels of this waste has been taken out in one night. It is particularly hard to remove from the screens, and in its emulsified state difficult to burn with the screenings.

The average sewage flow treated at the plant during 1918 was 6.04 m. g. d. Variations were estimated as being a million gallons either way or from 5 to 7 m. g. d. There were stoppages of treatment for 20 days during the year, and there is a wastage during high flows. The amount of this is not known, but, though probably a relatively small percentage of the total if taken over the year, it was sufficient to produce objectionable conditions at its point of discharge on the day of inspection.

The original plans of the treatment plant were prepared by Messrs. Hering & Fuller and Mr. Weand, who also designed the second and third filters constructed. Mr. Ulrich, the present city engineer, designed the last filter installed.

Sewage treatment at Reading dates back to 1895, but the start of the present plant was made in 1907, when Mr. O. M. Weand, who was given a five-year contract for treating the city's sewage, started construction. The plant then consisted of a Weand screen or segregator, followed by a septic tank, a trickling filter, and secondary sedimentation. Since then three new filter units have been added, one each in 1909, 1911, and 1915, each with a secondary sedimentation tank. The Weand screen has been abandoned and replaced by a stationary horizontal plate screen.

The city sewers discharge into one of two circular wells, in which a false bottom is formed by a plate screen with ½-inch holes on 2-inch centers. Below the screen is a shallow sump in which a little of the heavier grit is deposited. The screenings are pressed and burned.

The screened sewage is then pumped to a septic tank through a force main of 6,600 feet. The effluent from the septic tank flows by a gravity-pressure line through an inverted siphon under a branch of the Schuylkill River to Fritz's Island, where the trickling filters, four 1-acre units, and the secondary sedimentation tanks are located. The effluent from the secondary sedimentation tanks goes direct to the river.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE NO. 39.—*Results of chemical analyses at the Reading (Pa.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a.m.—	Suspended matter					Settleable solids, 2 hours c. c. per liter [1]				Oxygen consumed 30′ in boiling water				Alkalinity as $CaCO_3$ by M. O.				24-hour	Chlorine as chlorides			
	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw supernatant	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Ether soluble matter comp., raw [2]	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank
Aug. 6	----	74	30	29	36	----	Tr.	Tr.	Tr.	---	34	15	14	----	180	88	88	20	---	122	118	120
7	----	94	44	28	72	----	Tr.	Tr.	Tr.	---	26	12	10	----	180	96	100	22	---	120	125	120
8	----	68	38	20	50	----	Tr.	Tr.	Tr.	---	27	11	11	----	172	104	96	15	---	78	80	95
9	----	66	32	22	50	----	Tr.	Tr.	Tr.	---	23	12	10	----	184	92	98	16	---	68	78	73
10	----	100	44	18	66	----	Tr.	Tr.	Tr.	---	30	14	10	----	178	108	116	36	---	110	110	110
11	----	74	34	18	52	----	0.3	0.2	Tr.	---	31	18	15	----	180	120	120	18	---	102	105	105
12	----	88	56	34	76	----	Tr.	Tr.	Tr.	---	36	23	18	----	188	120	120	24	---	132	130	128
13	150	118	72	60	66	1.5	Tr.	Tr.	Tr.	43	31	23	18	168	180	120	120	38	125	100	100	100
14	168	100	92	60	70	2.0	Tr.	Tr.	Tr.	51	34	21	18	164	168	116	116	35	120	110	110	110
16	118	68	34	34	28	2.5	Tr.	Tr.	Tr.	42	36	15	15	160	160	89	100	24	115	110	115	115
Average	145	85	48	31	57	2.0	Tr.	Tr.	Tr.	45	31	16	14	164	177	105	107	25	120	105	107	108

24-hour sample ending 8 a.m.—	Biochemical oxygen demand at 20° ± C.								Dissolved oxygen		Hours to reduce M. B. at 20° ± C.				Nitrogen as nitrates	
	Raw		Effluent septic tank		Effluent trickling filter		Effluent secondary sedimentation tank		Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Effluent trickling filter	Effluent secondary sedimentation tank
											Per cent concentration					
	1-day	5-day	1-day	5-day	1-day	5-day	1-day	5-day			10	20	100	100		
Aug. 6	------	------	29	54	4.3	8	4.2	6	4.7	4.4	------	120+	120+	[5] 120+	6.5	9.5
7	------	------	26	57	3.8	5	3.0	6	4.4	4.0	------	48	120+	120+	7.0	7.5
8	------	------	46	106	5.3	15	2.8	12	4.5	5.1	------	24	120+	120+	3.8	4.0
9	------	------	28	80	3.0	13	2.6	8	5.4	5.0	------	48	120+	120+	5.5	6.5
10	------	------	60	136	10.0	28	5.0	24	3.1	2.8	------	24	120+	120+	4.0	6.0
11	------	------	56	124	10.0	26	7.5	24	3.8	3.9	------	24	120+	120+	1.2	0.9
12	------	------	54	114	14.0	26	4.5	17	0.6	0.0	------	48	120+	120+	2.8	1.0
13	56	128	50	110	11.0	28	9.5	23	4.0	4.8	72	[3] 72	120+	120+	2.4	3.2
14	68	108	56	84	16.0	27	10.0	18	4.0	4.1	72	[3] 72	96+	96+	3.2	2.8
16	------	------	------	------	------	------	------	----	4.5	4.0	[4] 48	48	48+	48+	7.5	7.5
Average	62	118	45	96	8.6	20	5.4	15	3.9	3.7	------	------	------	------	4.4	5.1

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[1] Tr. indicates less than 0.1 c. c. per liter.

[2] Effluent from septic tank (Aug. 6 to 12 incl.).

[3] 10 per cent concentration.

[4] 20 per cent concentration.

[5] 40 per cent concentration.

Sludge and scum from the septic tank are run onto a large area, djacent to the tank, which is cleaned once a year. The sludge rom the secondary tanks is applied to land on Fritz's Island. There re no specially prepared sludge beds.

The present sewage flow taxes the siphon line from the septic tank o Fritz's Island to its utmost. There is, moreover, frequently some xcess which this line can not carry and which overflows the tank irect into the river.

The entire flow of sewage can be by-passed at the pumping tation to the canal. At such times a small dose of hypochlorite f lime is added. As operated, this attempt at sterilization is of ttle or no value. This by-pass is used when work is being done n the septic tank or filters. After passing the tank, the filters an be by-passed into the river through a blow-off on the connectg line.

There is a laboratory and administration building on Fritz's sland, but its use as a laboratory has been abandoned and all such ork is done in the board of health laboratory in the city hall, the hemist only occasionally visiting the plant.

The regular personnel at the plant consists of 3 men covering he 24 hours on 8-hour shifts, so that ordinarily there is only one an on duty at a time. When needed for special jobs, such as eaning the secondary sedimentation tanks, an extra man or two provided, but the force at all times is totally inadequate.

The condition of the grounds reflects the lack of labor. They have e appearance of being semiabandoned after a start was made to rk and plant. Mud deposited by high water in the river in the ring of the year has been only partially removed. Considering e working force available, however, it is surprising that the conitions are not worse than they are.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 39.—*Results of chemical analyses at the Reading (Pa.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a.m.—	Suspended matter					Settleable solids, 2 hours c. c. per liter [1]				Oxygen consumed 30′ in boiling water				Alkalinity as $CaCO_3$ by M. O.				Ether soluble matter 24-hour comp., raw [2]	Chlorine as chlorides			
	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw supernatant	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank		Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank
Aug. 6	----	74	30	20	36	----	Tr.	Tr.	Tr.	---	34	15	14	----	180	88	88	20	---	122	118	120
7	----	94	44	28	72	----	Tr.	Tr.	Tr.	---	26	12	10	----	180	96	100	22	---	120	125	120
8	----	68	38	20	50	----	Tr.	Tr.	Tr.	---	27	11	11	----	172	104	96	15	---	78	80	95
9	----	66	32	22	50	----	Tr.	Tr.	Tr.	---	23	12	10	----	184	92	98	16	---	68	78	75
10	----	100	44	18	66	----	Tr.	Tr.	Tr.	---	30	14	10	----	178	108	116	36	---	110	110	110
11	----	74	34	18	52	----	0.3	0.2	Tr.	---	31	18	15	----	180	120	120	18	---	102	105	105
12	----	88	56	34	76	----	Tr.	Tr.	Tr.	---	36	22	18	----	188	120	120	24	---	132	130	125
13	150	118	72	60	66	1.5	Tr.	Tr.	Tr.	43	31	23	18	168	180	120	120	38	125	100	100	100
14	168	100	92	60	70	2.0	Tr.	Tr.	Tr.	51	34	21	18	164	168	116	116	35	120	110	110	110
16	118	68	34	34	28	2.5	Tr.	Tr.	Tr.	42	36	15	15	160	160	89	100	24	115	110	115	115
Average	145	85	48	31	57	2.0	Tr.	Tr.	Tr.	45	31	16	14	164	177	106	107	25	120	105	107	108

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.								Dissolved oxygen		Hours to reduce M. B. at 20° ± C.				Nitrogen as nitrates	
	Raw		Effluent septic tank		Effluent trickling filter		Effluent secondary sedimentation tank		Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent septic tank	Effluent trickling filter	Effluent secondary sedimentation tank	Effluent trickling filter	Effluent secondary sedimentation tank
											Per cent concentration					
	1-day	5-day	1-day	5-day	1-day	5-day	1-day	5-day			10	20	100	100		
Aug. 6	-----	-----	29	54	4.3	8	4.2	6	4.7	4.4	------	120+	120+	[5] 120+	6.5	9.5
7	-----	-----	26	57	3.8	5	3.0	6	4.4	4.0	------	48	120+	120+	7.0	7.5
8	-----	-----	46	106	5.3	15	2.8	12	4.5	5.1	------	24	120+	120+	3.8	4.0
9	-----	-----	28	80	3.0	13	2.6	8	5.4	5.0	------	48	120+	120+	5.5	6.5
10	-----	-----	60	136	10.0	28	5.0	24	3.1	2.8	------	24	120+	120+	4.0	6.0
11	-----	-----	56	124	10.0	26	7.5	24	3.8	3.9	------	24	120+	120+	1.2	0.9
12	-----	-----	54	114	14.0	26	4.5	17	0.6	0.0	------	48	120+	120+	2.8	3.0
13	56	128	50	110	11.0	28	9.5	23	4.0	4.3	72	[3] 72	120+	120+	2.4	3.2
14	68	108	56	84	16.0	27	10.0	18	4.0	4.1	72	[3] 72	96+	96+	3.2	2.5
16	-----	-----	-----	-----	-----	-----	-----	-----	4.5	4.0	[4] 48	48	48+	48+	7.5	7.5
Average	62	118	45	96	8.6	20	5.4	15	3.9	3.7	------	------	------	------	4.4	5.1

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[1] Tr. indicates less than 0.1 c. c. per liter.

[2] Effluent from septic tank (Aug. 6 to 12 incl.).

[3] 10 per cent concentration.

[4] 20 per cent concentration.

[5] 40 per cent concentration.

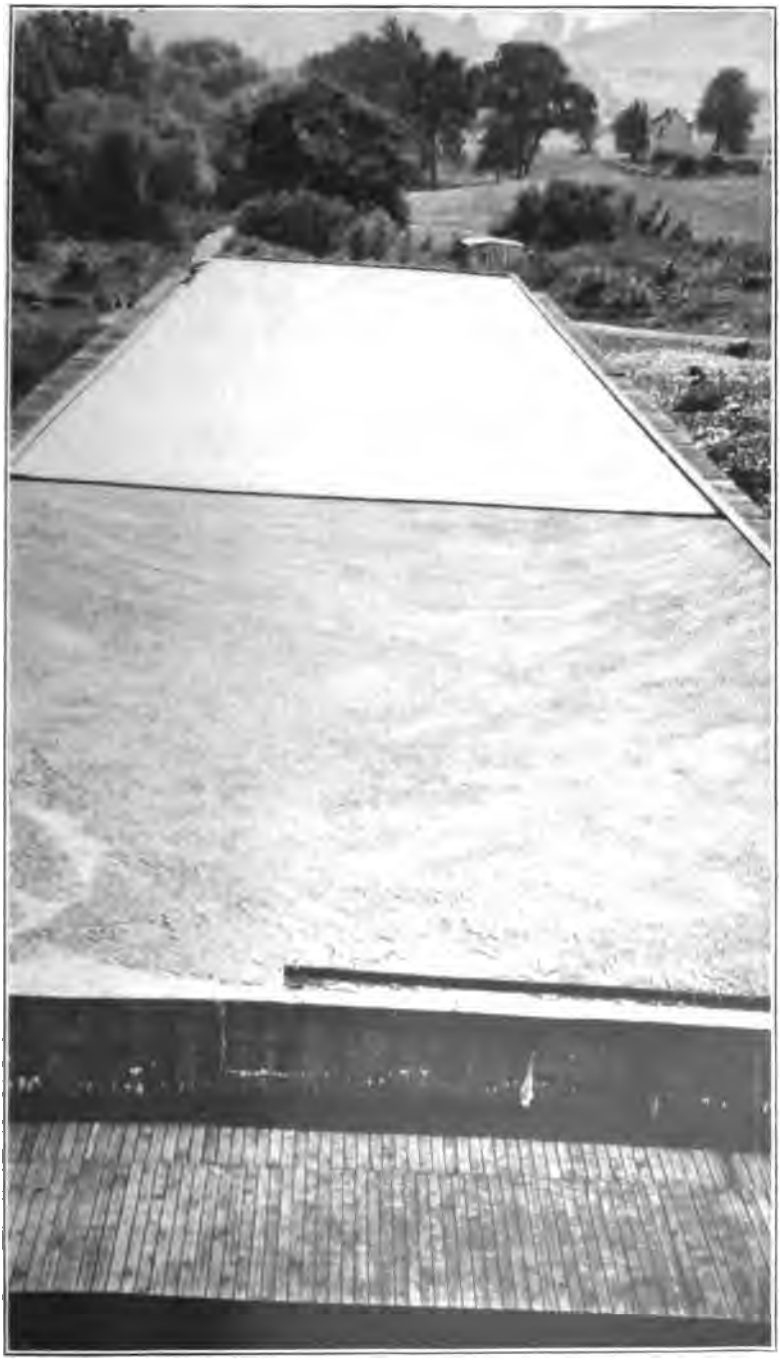


FIG. 17.—SEPTIC TANK AT READING, PA., SHOWING MOVABLE BAFFLE WITH SCUM AHEAD AND CLEAR SURFACE BEHIND

Only three samples of raw sewage were analyzed. This was because of the difficulty of obtaining and transporting them. The only point at which samples could be obtained was at the pumping station, as the sewage enters the septic tank direct from the force main 5 to 6 feet below the surface of the sewage in the tank. The pumping station is located some 2 miles by road from the septic tank. It was impossible, therefore, for the sample collectors to cover all the desirable sampling points. Toward the end of the studies, however, arrangements were made with the engineer at the pumping station for the collection of the three samples analyzed.

Based on the three samples, the raw sewage appears to be very close to the average obtained on the survey. The suspended solids are about 10 per cent low, but the oxygen consumed and the 5-day oxygen demand are almost exactly the same as the average. It is believed that these results are representative. In 1918 the average for the year for suspended solids and oxygen consumed determinations made by the chemist at the plant were 130 and 50, respectively, neither of which results are far from those discussed above.

The results of the analyses of the effluent from the septic tank require no special comment. They indicate a normal septic tank effluent at a time when it is operating with very little unloading.

The final effluent from the plant, as based on the analyses made, which, with the exception of the nitrates, are in close agreement with those made by the local chemist, is entirely satisfactory for disposal by dilution in the Schuylkill River. The minimum river flow in 1914, when the river was considered unusually low, was 190 second-feet. This is sufficient for a dilution factor of 17 for a very high sewage flow of 7 m. g. d. For a normal sewage flow the least dilution would be about 20, with an average dilution of probably 25–35. Even much smaller dilutions would suffice, as the plant effluent is of a good character, with a low suspended solid content of 31 parts per million, a 5-day oxygen demand of only 15, for which is available in the sewage itself dissolved oxygen and nitrates and nitrites of 3.7 and 5.0 parts per million, respectively. Considering the very limited supervision and attention to operation which the small personnel can give, the character of the effluent is surprisingly good.

Accurate construction costs were not obtainable. The septic tank was made by remodeling an old double-deck filter, and this work, together with some of the filter installation, was done under a lump-sum contract, which also included the operation of the plant. The city in 1918 appraised the entire sewage-treatment system at $426,-821.38. This figure, however, includes the pumping station, force main to the septic tank, and other items required by purely local conditions.

The budget estimate of the cost of operation for 1920 but this figure also includes the pumping station, whe two-thirds of the total appropriation is spent. It is not pute from it the cost of treatment alone.

X. Rochester, N. Y.

At Rochester, N. Y., two plants were surveyed wh different in design and operation that it is not possibl them together, as was done with the two plants at Atlan Houston, Tex. The sewerage system and raw sewage separate treatment. With the exception, therefore, of statement of the size and character of the city as a whol ment plants will be taken up separately.

Rochester is a city of 296,000 population, located i western part of New York on Lake Ontario. It is primar trial city containing many large plants engaged in the of a wide range of products. The majority of these, how produce liquid wastes. The residential sections are, for th very attractive.

A. BRIGHTON SEWAGE TREATMENT PLANT

The engineering survey of the Brighton sewage trea at Rochester, N. Y., was made June 21 to 23, 1920. Th studies followed one month later, July 16 to 24.

The sewerage system tributary to the plant is of the tary type, there being very few, if any, roof drains a storm drains connected. Infiltration is, however, consi high. No exact data are available regarding its volume, mated to run 25 to 50 per cent of the total sewage flow.

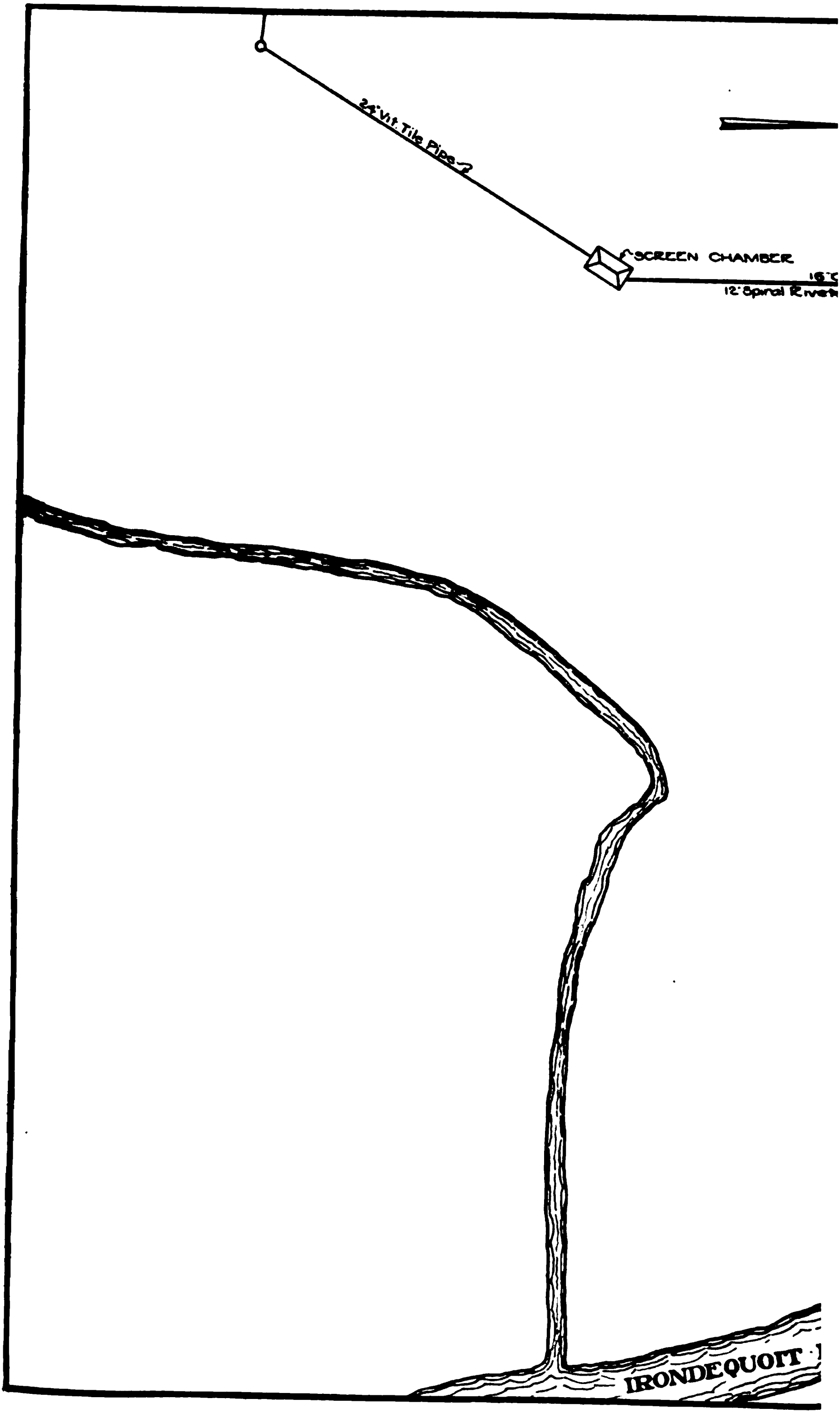
Topography permits the uniform use of good grades, being the flattest used.

The total mileage of sewers is 20, divided as follows:

	Linear feet		
8-inch	83, 453	18-inch	
10-inch	5, 992	20-inch	
12-inch	3, 910	24-inch	
15-inch	3, 618		

To these there are 1,215 sanitary connections, serving population of 8,000, or 6.4 persons per connection.

All flushing is done by automatic flush tanks which a all dead ends and at points where the velocity of flo sewers are running one-half full, is less than five feet pe


24" Vit. Tile Pipe
SCREEN CHAMBER
16" C
12" Spiral Rivet
IRONDEQUOIT ·

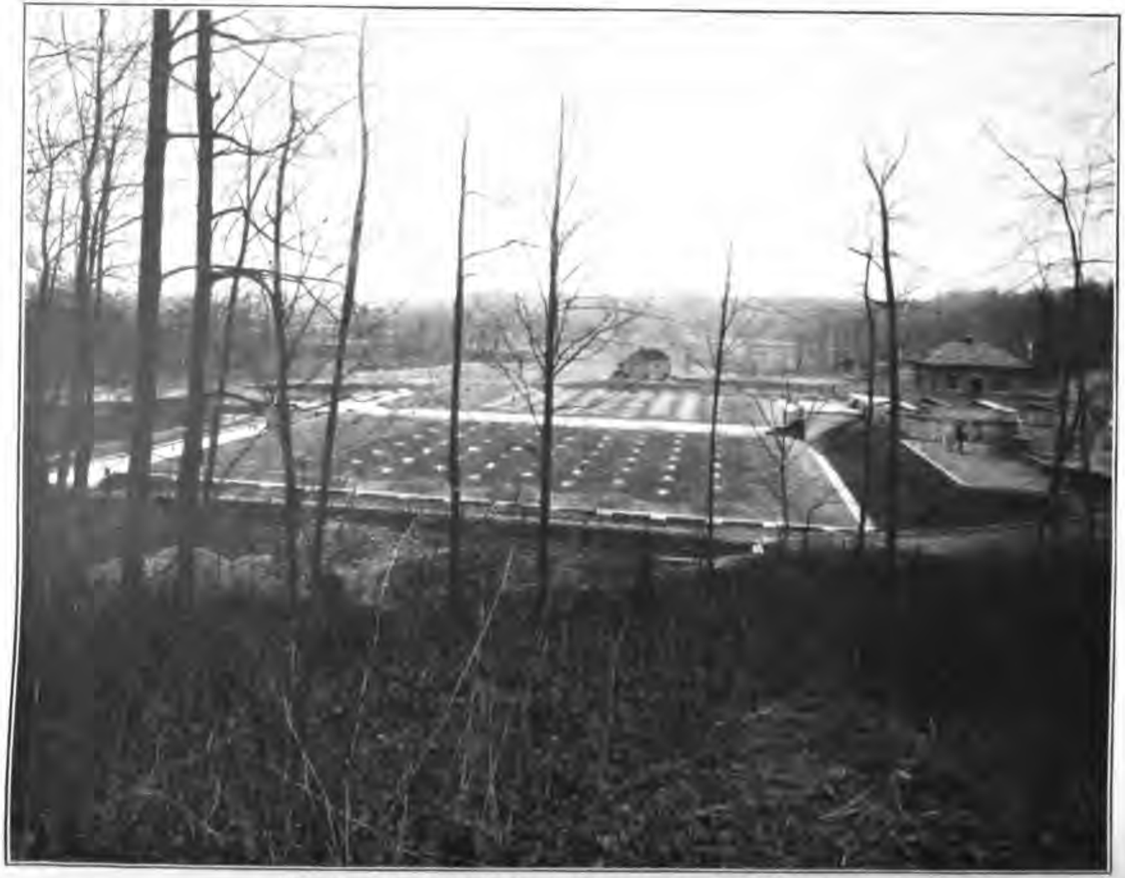


FIG. 19.—THE BRIGHTON PLANT AT ROCHESTER, N. Y.

Mention may be made of a small pumping plant consisting of two 50-gallon Pacific Flush Tank Co.'s automatic ejectors, which serve a very small section in the tributary area; in fact, only one house was connected to this system at the time of inspection, June, 1920.

There is one overflow point on the entire system of tributary sewers, and this one is said to operate but rarely. It is also available and can be used as a complete by-pass around the treatment plant.

The raw sewage is strictly domestic, with no surface storm waters and negligible amount, if any, of industrial wastes. There is, however, considerable dilution by infiltration, which, as already stated, is estimated to amount to at least 25 per cent and probably 50 per cent of the entire flow.

The tributary area is comparatively small, and all within a relatively short distance from the plant, so that the sewage has not far to travel. It is, therefore, quite fresh. This is indicated by the unbroken condition of the suspended solids and the odor typical of fresh sewage.

The volume of sewage is measured over a trapezoidal weir at the outlet of the plant. There is an indicating but not a recording device, so that readings are taken three times daily, at 7.30 a. m., 12 noon, and 5 p. m. No readings are taken during the night as there is no one at the plant after 5 p. m.

The average flow for the year 1918 was 1.02 m. g. d. This figure may be in excess of the actual amount, due to the fact that it is based on the day readings and fails to take in the lower night flows. The lowest 24-hour flow in 1918 was 0.71 m. g., occurring on January 31, and the highest flow was 1.76 m. g., occurring on February 15.

The treatment plant was designed by John F. Skinner, principal assistant engineer in the city engineer's office. The plans were approved by F. T. Elwood, former city engineer, and E. A. Fisher, consulting engineer, and the general method of disposal was passed upon by George C. Whipple. Bids were received for construction in April, 1915, and actual operation of the plant started March 1, 1916.

The main sewer to the plant discharges into a channel from which it was originally planned to take sewage through one of three parallel baffled grit chambers. As actually operated, however, one of the original grit chambers has been converted into a narrow inlet channel, which is used most of the time, with the actual grit chambers in reserve and ready to operate under unusual conditions, such as a break or washout in a sewer, when an abnormal amount of grit might be carried by the sewage. At the outlet end the sewage passes under a scum board onto an inclined bar screen, and from there to a discharge chamber. From this the sewage is discharged either through a cast-iron pipe to a Pelton water wheel located in the operating house, or through a 12-inch overflow pipe to the operating house and thence to the Imhoff tanks. The grit chambers, screens, etc., are housed in an attractive tapestry brick building.

All sewage is settled in an Imhoff tank which is designed with parallel sides but semicircular ends. There are inlet and outlet scum boards but no other baffles. The inlet and outlet channels are arranged to permit the reversing the direction of flow through the tank.

The effluent channel from the Imhoff tank carries the sewage to a triangular siphon chamber, which contains the siphons discharging into the dosing tanks of the trickling filters.

The filter area is divided into two units, each operated by a separate dosing tank, as mentioned above. The effluent from the filters is collected in two secondary sedimentation tanks, one for each filter, from which the final effluent pipe carries the sewage to a submerged outlet in the Irondequoit River.

Two underdrained specially constructed sludge beds are located just west of the Imhoff tanks. These have not, however, been used for the past two years, as it has been found more advantageous to dispose of sludge in a low lagoon about 500 feet north of the tank, but well concealed from the plant by trees and other growth.

There are no laboratory facilities located at the plant itself. All such work is done at the other sewage-treatment plant. Here the laboratory is very well equipped, but during the past season little, if any, chemical work has been done. Three laborers maintain the regular operation of the plant during the day, there being no one on duty at night. In addition, extra labor is furnished from time to time for handling sludge, road work, grading, and special jobs.

Few plants are located in such favorable natural surroundings or give evidence of as careful and intelligent care of the grounds as is the case at this plant. Their general appearance disguises, even to the average prejudiced mind, the real purpose of the plant to such an extent that they are frequently used for picnics.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 40.—*Results of chemical analyses at the Rochester Brighton sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter.					Settleable solids, 2 hours, c. c. per liter [1]				Oxygen consumed 30' in boiling water				Alkalinity as $CaCO_3$ by M. O.				Ether soluble matter 24-hour comp., raw	Chlorine as chlorides			
	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw supernatant	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank		Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank
July 16	107	42	24	11	23	2.0	Tr.	Tr.	Tr.	15	10	6.4	4.0	184	188	108	130	14	42	43	42	42
17	88	22	44	12	33	2.5	Tr.	Tr.	Tr.	34	15	7.7	5.4	145	190	140	135	18	46	44	44	44
18	76	26	20	13	----	1.5	Tr.	Tr.	Tr.	23	15	10.0	6.8	175	182	128	125	12	42	45	42	40
19	134	40	24	4	18	1.5	Tr.	Tr.	Tr.	18	9	8.0	6.8	200	200	140	135	18	42	45	45	45
20	144	70	28	22	28	3.0	Tr.	Tr.	Tr.	32	22	9.8	7.2	185	190	135	130	22	65	45	48	42
21	84	44	40	4	16	1.5	Tr.	Tr.	Tr.	22	16	13.0	5.9	180	180	135	135	12	45	45	45	48
22	94	40	28	8	13	2.0	Tr.	Tr.	Tr.	30	15	15.0	7.1	170	195	135	125	18	39	45	45	45
23	80	36	26	8	11	2.0	Tr.	Tr.	Tr.	16	17	8.2	4.6	185	190	130	130	14	41	45	42	42
Average	101	40	29	10	18	2.0	Tr.	Tr.	Tr.	24	15	9.7	5.9	178	189	131	131	16	45	45	44	44

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.								Dissolved oxygen			Hours to reduce M. B. at 20° ± C				Nitrogen as nitrates	
	Raw		Effluent Imhoff tank		Effluent trickling filter		Effluent secondary sedimentation tank		Raw	Effluent trickling filter	Effluent secondary sedimentation tank	Raw	Effluent Imhoff tank	Effluent trickling filter	Effluent secondary sedimentation tank	Effluent trickling filter	Effluent secondary sedimentation tank
												Per cent concentration					
	1-day	5-day	1-day	5-day	1-day	5-day	1-day	5-day				20	20	100	100		
July 16	20	40	8	20	2.0	7.2	1.0	4.6	6.3	8.0	9.0	120	120+	120+	120+	3.3	4.2
17	36	142	8	34	1.7	7.2	1.5	5.7	----	7.6	8.7	48	72	192+	192+	4.0	4.0
18	22	58	10	36	2.1	6.9	1.7	5.1	3.9	7.5	7.9	[2] 46	[2] 72	192+	192+	3.0	3.6
19	14	56	8	32	2.1	7.5	1.2	5.9	4.6	7.8	8.0	70	192+	192+	192+	1.4	0.8
20	32	96	31	72	3.3	-----	2.6	-----	.4	7.0	7.5	28	28	168+	168+	1.8	1.6
21	28	66	8	40	2.8	-----	1.5	6.4	2.2	6.5	7.4	120	52	144+	144+	3.2	2.6
22	14	46	6	32	1.6	7.0	1.0	4.4	3.4	6.8	7.9	120	120+	120+	120+	2.2	2.2
23	14	40	12	34	3.1	7.3	1.3	4.9	4.8	7.5	8.2	120+	120+	120+	120+	3.6	4.4
24	22	58	6	24	3.6	7.1	2.3	5.0	4.4	7.8	7.9	72	120+	120+	120+	-----	-----
Average	22	67	11	36	2.5	7.1	1.6	5.2	3.7	7.4	8.0	------	------	------	------	2.8	2.9

[1] Tr. indicates less than 0.1 c. c.
[2] 40 per cent concentration.

The raw sewage is unusually weak, probably due to the large percentage of infiltration water it contains. This dilution is particularly noticeable in the chlorine content, which is only about one-half the next lowest value obtained in these studies. All other determinations upon which the concentration of a sewage may be judged are also low. With the exception of the 5-day oxygen demand which is lower at the Atlanta plants, and equaled at San Marcos, the values obtained in the other critical determinations are the lowest found during the survey. That the sewage is exceptionally fresh is evidenced by the high value of the dissolved oxygen. This constituent too is materially affected by the ground water of infiltration.

Few plants have as large a margin of safety against any possible nuisance from the final effluent as has this one. The character of the effluent is exceptionally high, well above the average found in the survey, the dissolved oxygen content alone being over 50 per cent higher than the 5-day demand. There is no danger of any deposition of the 10 parts per million of suspended solids.

In addition to the character of the effluent itself, the dilution in the Irondequoit River is always very high. The only evidence of sewage entering the river at the point of discharge on the day of inspection was an agitation in the water and the bulkhead on the shore.

The total cost of the construction of the plant was $119,451, divided as follows:

A. Site with pipes, outlet, etc.	$28, 708
B. Screen house and grit chambers	6, 164
C. Imhoff tank, sludge beds, and operating house	19, 499
D. Dosing device, trickling filters, and secondary tanks	57, 819
E. Power development, electrical and mechanical equipment, laboratory equipment	7, 261
Total	119, 451

It is not possible to compute from these figures a fair cost per million gallons, since much construction work is completed for a plant double the capacity of the present one. Thus the filter gallery, part of the dosing device, the grit chambers, screen house, and other buildings have been built complete for an estimated future growth of the plant.

In the 1919 annual report of the engineer and chemist in charge of operation of the plant the following summary of maintenance and operating costs is made:

Superintendence	$187. 50
Labor	2, 555. 60
Maintenance supplies, repairs, telephone, water	372. 93
Total	3, 116. 03

On the basis of 390 million gallons treated during that year, the cost per million gallons is $7.90. In addition to the above expenditures, the park department spent in labor on the park gang $3,420.30 This was for the maintenance of the park grounds around the treatment plant.

B. IRONDEQUOIT SEWAGE-TREATMENT PLANT

The engineering survey of the Irondequoit sewage-treatment plant at Rochester, N. Y., was made June 17 to 22, 1920. The laboratory studies followed one month later, July 14 to 30.

The sewerage system tributary to the plant is of the combined type. It is estimated to serve a population of 240,000. Infiltration is estimated to amount, on an average, to about 2 m. g. d. for the entire system.

The topography allows good grades for the most part, averaging 0.5 per cent. The minimum is considered sufficient to insure self-cleaning velocities, and no direct flushing of any nature is done. Data covering the mileage of the various size pipes or the mileage of the entire system were not available.

There are eight storm overflows on the system which operate when the flow becomes three and one-half times the dry weather flow. The dry flow accepted for the design of the overflows was 34 m. g. d. so that the rate would reach 120 m. g. d. before there is any overflow. Since the design several of the districts have built up and the overflow control has been readjusted to allow for the increased flow.

To collect and remove the grit in the sewers there are installed two sand catchers. These are ahead of the inverted siphons which carry only one-half the total sewage flow. From both of them the total removal in 1919 was 3,189 cubic feet, or an average of 9 cubic feet per day. With an average flow of over 17 m. g. d. during the year, the grit removed amounts to less than 0.6 of a cubic foot per million gallons, which is only a very small per cent of the total carried by the sewage.

The raw sewage received at the treatment plant is of the combined type. There is a considerable period of travel in the sewers, and the sewage reaches the plant in a stale condition. The suspended solids are pretty well broken up and water-soaked. Matches and small sticks were observed floating on the surface and pieces of paper, fecal matter, fruit and vegetable seeds, and skins suspended in the sewage.

Industrial wastes are practically negligible. A small dye plant and a slaughterhouse are connected to sewers tributary to the plant, but the waste is treated before entering the sewers. The dye-plant wastes at times impart a distinct color to the sewage, but, so far as scertainable, do not affect the treatment processes.

The average dry-weather flow is 32 to 33 m. g. d. and the maximum low at the plant for any one day from January, 1918, to April, 1920, both inclusive, was 59.64 m. g. The maximum rate of flow has been ver 150 m. g. d. This exceeds the original design, but is due to djustments of the regulating devices to control increased dry flows.

The plant, situated on Lake Ontario, serves all the city except a relatively small section tributary to the Brighton plant, and also the Charlotte, Skunk Hollow, and Maplewood territories to the north and west.

The sewage is measured on entering the plant by a recording Venturi meter. The first treatment device consists of coarse bar screens with 3-inch clear openings at the entrance to the grit chambers. Six of these are in place, but only four used to any extent, the other two being available for by-passing around the fine screens which follow the grit chambers. The grit chamber installation is sufficient for future growth of the plant to double its present capacity. A traveling "A" crane derrick excavator with a clam-shell bucket is used for cleaning. Grit is removed without draining the chambers and, during the winter, without interference with continuous operation.

From the grit chambers the sewage passes to Riensch-Wurl screens 12 feet in diameter. There are four of these in place, each served by a separate grit chamber as influent channel. These screens are housed in a large attractive brick building which also contains the workshop, laboratory, toilets, etc.

From the screens the sewage enters the influent channels of the Imhoff tanks, of which there are ten arranged in five units of two each. These tanks are rectangular, of the double flow chamber, reversible type, and of extra large sludge capacity.

The effluent from the tanks is either run through a hydroelectric plant or discharged direct into the lake through a submerged outlet 7,000 feet offshore.

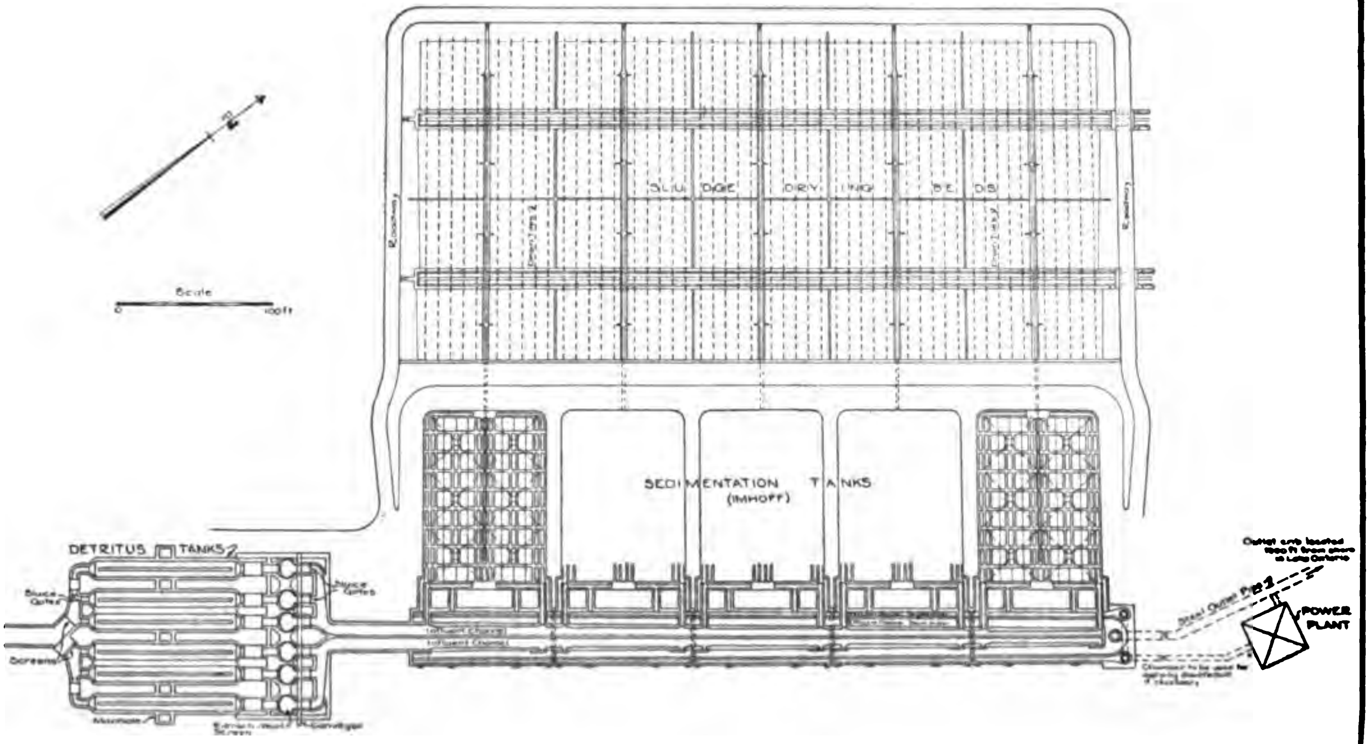
Adequate sludge beds are located adjacent to the Imhoff tanks. These are cleaned by hand into the bodies of small cars which are lifted from their trucks and placed on the bed by a gantry crane. When full the crane replaces them on their trucks and they are hauled by an electric engine to the dump.

The arrangement of the plant is such that the Riensch-Wurl screens and the Imhoff tanks can be by-passed.

Laboratory facilities are exceptionally good, and the equipment is adequate. At the time of inspection, however, no laboratory work was being done. This laboratory serves the Brighton sewage treatment plant also.

The personnel, in addition to the chemist, consists of a chief engineer in charge of the operation of the plant, an engineer, two tank operators, relief man, mechanic, electrician, labor foreman, and 17 laborers.

The appearance of the plant is very attractive. The grounds are kept clean and, while no extensive parking or planting has been done, the location of the plant and its natural surroundings are such as to make a favorable impression.


Scale
0
100 ft
Roadway
SLUDGE DRYING BEDS
Roadway
SEDIMENTATION TANKS
(IMHOFF)
DETRITUS TANKS
Sluice Gates
Screens
Manhole
Sluice Gates
Influent Channel
Steel Outlet Pipe
POWER PLANT

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 41.—*Results of chemical analyses at the Rochester Irondequoit sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter				Settleable solids, 2 hours, c. c. per liter			Oxygen consumed 30′ in boiling water			Alkalinity as $CaCO_3$ by M. O.			Ether soluble matter 24-hour comp., raw	Chlorine as chlorides		
	Raw	Effluent screens (R.-W.)[1]	Effluent Imhoff tank	Raw supernatant	Raw	Effluent screens (R.-W.)[1]	Effluent Imhoff tank	Raw	Effluent screens (R.-W.)[1]	Effluent Imhoff tank	Raw	Effluent screens (R.-W.)[1]	Effluent Imhoff tank		Raw	Effluent screens (R.-W.)[1]	Effluent Imhoff tank
July 14	128	164	110	37	2.0	2.0	0.4	29	38	24	184	180	192	40	88	93	[illegible]
15	160	194	136	39	2.0	2.5	.7	49	48	44	174	174	184	34	84	89	94
16	104	126	94	50	2.5	2.7	1.0	35	34	33	184	180	204	27	90	90	[illegible]
17	104	94	82	65	1.0	1.5	.1	35	33	34	180	180	200	21	84	86	[illegible]
18	154	202	88	34	3.0	3.0	1.5	50	51	42	190	180	180	56	90	95	[illegible]
19	336	372	134	20	4.5	4.5	.1	60	58	38	140	160	180	50	65	70	75
20	110	112	110	58	.8	1.5	1.2	41	44	39	184	184	188	35	86	86	[illegible]
21	102	124	120	42	1.5	1.5	.5	36	48	35	184	188	196	30	88	90	[illegible]
22	364	380	144	53	3.2	3.5	1.1	40	47	28	160	160	180	34	80	75	85
23	144	124	100	44	1.5	1.5	.1	32	44	33	176	172	196	21	80	80	[illegible]
24	378	310	139	48	2.0	2.5	.4	41	51	39	146	148	168	----	75	75	[illegible]
25	257	283	146	110	1.1	1.4	.1	23	35	27	176	176	196	----	80	82	[illegible]
27	197	204	138	60	2.0	2.0	.7	41	42	32	184	184	196	26	80	80	[illegible]
28	133	134	132	44	2.0	2.2	1.0	39	36	31	176	174	188	31	75	75	83
29	143	146	109	57	2.0	2.2	1.1	39	46	42	186	188	198	----	84	82	[illegible]
Average	188	198	119	50	2.1	2.3	.7	39	44	35	175	175	190	34	82	83	86

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.						Dissolved oxygen, raw	Hours to reduce M. B. at 20° ± C.					
	Raw		Effluent screens (R.-W.)[2]		Effluent Imhoff tank			Raw		Effluent screens (R.-W.)[2]		Effluent Imhoff tank	
								Per cent concentration					
	1-day	5-day	1-day	5-day	1-day	5-day		10	20	10	20	10	20
July 14	45	105	65	120	32	76	0.0	120	[3]120+	120+	------	120+	------
15	52	76	44	92	36	80	3.6	96	72	120	------	120+	72
16	48	116	28	140	36	80	1.9	120+	96	120+	------	120+	72
17	44	108	44	104	36	76	.0	------	48	------	48	------	72
18	60	------	56	140	40	108	.0	------	48	------	48	------	48
19	36	160	36	104	16	76	.4	------	47	------	47	------	[illegible]
20	40	120	40	100	28	96	.0	------	23	------	23	------	[illegible]
21	56	96	56	108	28	80	.0	72	24	144+	------	144+	48
22	48	92	32	100	24	44	.0	120	------	120	------	120	------
23	44	96	44	84	36	64	1.6	96	------	120	------	120+	------
24	40	76	40	72	28	64	.0	120+	------	120+	------	120+	------
25	24	52	16	44	12	36	2.2	72	------	120+	------	120+	------
27	48	156	48	96	36	76	4.4	72	------	96+	------	96+	------
28	------	------	------	------	------	------	.0	96+	------	96+	------	96+	------
29	------	------	------	------	------	------	.0	48	------	48	------	48	------
Average	45	104	42	100	30	74	.9	------	------	------	------	------	------

[1] ⅜-inch screen used July 14–18, inclusive; ⅛-inch, July 19–23, inclusive; 1/16-inch, July 24–29, inclusive.
[2] ⅜-inch screen used July 14–18 inclusive; ⅛-inch, July 19–23 inclusive; 1/16-inch, July 24–29 inclusive.
[3] 5 per cent concentration.

The raw sewage is about the average of those studied on this survey. The suspended solids are a little high, but the oxygen consumed slightly lower than the average. The presence of dissolved oxygen in six of the nine samples analyzed, and in several of these samples in fairly large amounts, seems to contradict the statement previously made that the sewage was stale. The statement referred to normal dry weather flow, and not to conditions of storm flow, which existed at the time the samples showing the dissolved oxygen were taken.

The interesting feature of this plant and the primary reason for its selection for study were the Riensch-Wurl screens. These are discussed in considerable detail in another section of this report, but it is of interest at this point to call attention to the increase of 10 parts per million in the suspended solids after passing the screens. Similar results have been obtained elsewhere, and it is believed to be due to imperfect methods of sampling and analysis, the coarse particles which are removed by the screens not being included in a sample taken for the suspended solids determination by the Gooch crucible. Comparing the results of other determinations on the screen effluent with those for raw sewage, it is found that they are almost identical. From the analyses, the action of these screens as a treatment device is negligible. For further discussion of screens, and their efficiency as based on the volume of the screenings removed, reference is made to page 171.

At this plant the final effluent is that from the Imhoff tanks. As the ultimate disposal is by dilution in Lake Ontario where the dilution factor is tremendous, the primary function of the treatment plant is to remove large floating particles that might cause surface nuisance on the lake or be washed ashore and create objectionable conditions there. As judged by the analyses in the above table, the efficiency of the Imhoff tanks is below normal, the removal of suspended solids being only about 40 per cent and the settleable solids 69 per cent. The solids are, however, of such character that they do not create objectionable conditions in the lake or on the shores. Several attempts have been made to locate the outlet in the lake with boats, but they have all been unsuccessful.

The total cost of the construction of the plant was $988,500. This figure, however, includes the hydroelectric installation, which, while introducing possible economies in operation, is not an integral part of the treatment plant. The cost of the outfall sewer from the city to the plant is not included in the above figure.

The operation and maintenance cost for the year 1919 are given as $30,809, divided roughly as follows:

Salaries	$12, 519
Labor	12, 065
Supplies and materials	6, 225

XI. San Marcos, Tex.

The engineering survey of the sewage treatment plant at San Marcos, Tex., was made August 25 to 27, 1920. The laboratory studies followed about two and a half months later, November 3 to 12.

San Marcos, Tex., is a town of about 5,000 population, located on the San Marcos River in the eastern part of Texas, between Austin and San Antonio. It is primarily a trading point for the surrounding agricultural districts, there being no industries of any size. The State normal school is located here, and a considerable part of the population is centered in this institution.

The sewage system is entirely of the separate type, with probably a few roof drains illegally connected.

Infiltration and leakage factors were not ascertainable. It was stated by Mr. Wilson, manager of the Utilities Co., that infiltration was probably not large, but that there was considerable leakage through manhole covers. At any rate very heavy storms effect temporary increase in flow.

No data were obtainable covering the sizes or mileage of the sewers included in the sewerage system. The grades were stated to be quite steep, so that very little flushing and draining is necessary. There are 23 automatic flush tanks on the system.

The sewerage system as well as the treatment plant is owned by the Sewer Co. of San Marcos, and charges are made for individual connections and service. Connection to the sewers, even where available, is not compulsory. As a result only about one-half of the population of about 5,000 is estimated as served by the sewers through 366 connections.

There are no specially prepared overflows on the system, but at the entrance to the treatment plant the sewage passes through a small box which has, at times of heavy rains, overflowed, the sewage running over the ground to the river about 20 feet distant.

The raw sewage is typically domestic, fresh, and diluted by some ground water that is constantly entering the sewers by infiltration. During wet weather, this, with the leakage through manhole covers and a few connected roof drains, probably constitutes a fairly high percentage of the total flow. There are no industrial wastes entering the sewers.

No measurements of flow are made by the local officials, but they estimate it at 60 gallons per capita per day for a population of 2,500. During the period covered by the laboratory studies a 12-inch weir was installed at the outlet of the treatment plant and readings taken hourly. These measurements showed variations from 168,000 to 256,000 gallons per day, with an average of 203,000. This is equiv-

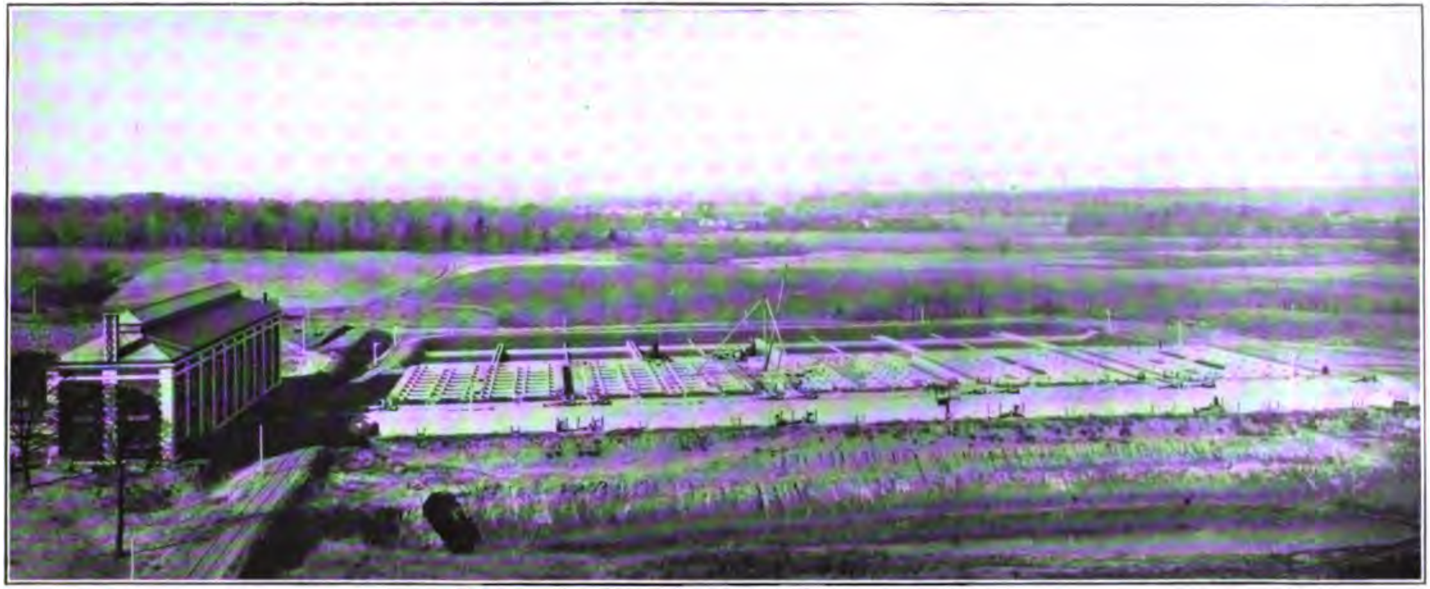


FIG. 21.—THE IRONDEQUOIT PLANT AT ROCHESTER, N. Y.

Excavation in the foreground is in preparation for possible duplication of tanks to the right of the channels

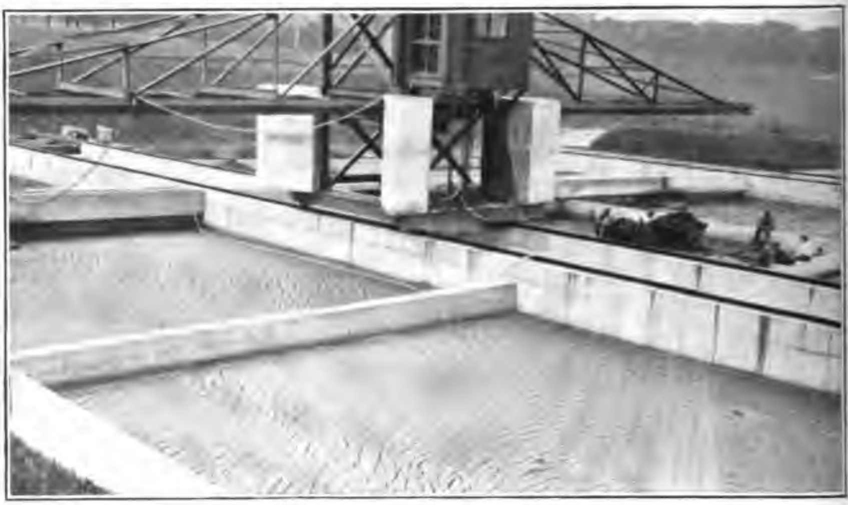


FIG. 22.—SLUDGE BEDS AT THE IRONDEQUOIT PLANT AT ROCHESTER, N. Y.

lent to 80 gallons per capita for the estimated contributing population of 2,500.

The sewage-treatment plant is located just across the San Marcos River and about one-half mile distant from the center of the town.

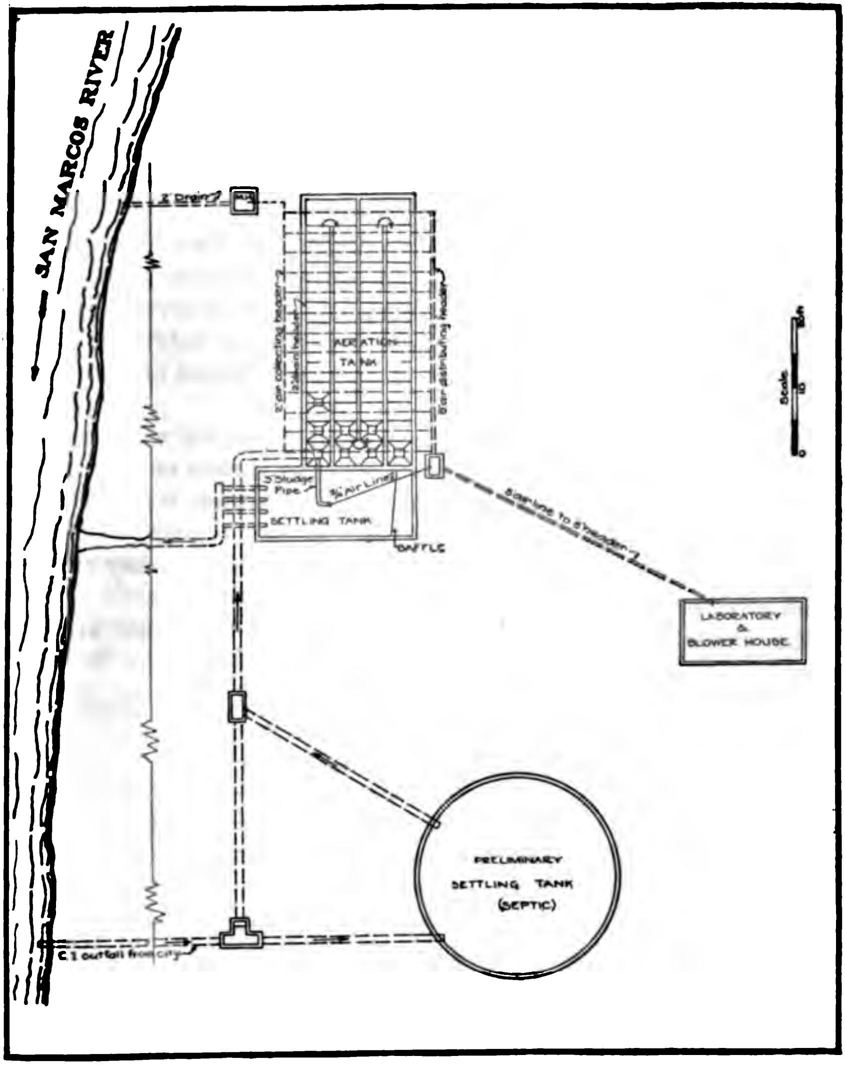


FIG. 23.—General plan of the sewage-treatment plant at San Marcos, Tex.

The present plant was designed by Ashley F. Wilson and put into operation in 1916, replacing a plant consisting of sedimentation and broad irrigation. At the present time, the sedimentation tank of the old plant is embodied in the new plant.

The sewage first enters the sedimentation tank operated as a septic tank. This is circular and of large capacity in proportion to the flow. The sewage, however, does not flow across the tank, but leaves at a point not far from the inlet. This outlet is surrounded by a box covered with a galvanized-iron mesh screen.

From the septic tank the sewage passes to the aeration tank consisting of four channels in series with filtros blocks for aerators. The effluent from this tank goes to the final sedimentation tank, and thence to the San Marcos River.

There is no sludge reaeration tank, the sludge from the final sedimentation tank passing directly back to the inlet of the sewage aeration tank.

Sludge disposal has presented little difficulty. Two beds, 12 feet square, are provided for sludge from the activated sludge process. In addition, some adjacent low-lying land has received several applications of sludge. The septic tank has been cleaned only once in the past three years, at which time the sludge was pumped onto the land formerly used for broad irrigation.

There are no laboratory facilities and no analytical work is done. One man gives part time to the plant, visiting it once or twice a day, primarily to oil the motors and blowers. When there is special work to do, extra labor is provided.

No effort has been made to improve the grounds; but they are kept clean, and there is nothing objectionable about the plant.

The results of the chemical analyses made at this plant are contained in the following table:

Table No. 42.—*Results of chemical analyses at the San Marcos (Tex.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter				Settleable solids, 2 hours c.c. per liter.[1]		Oxygen consumed 30′ in boiling water			Alkalinity as $CaCO_3$ by M. O.			Ether soluble matter 24 hours comp., raw	Chlorine as chlorides		
	Raw	Effluent septic tank	Effluent final sedimentation tank	Raw supernatant	Raw	Effluent septic tank	Raw	Effluent septic tank	Effluent final sedimentation tank	Raw	Effluent septic tank	Effluent final sedimentation tank		Raw	Effluent septic tank	Effluent final sedimentation tank
Nov. 3	-----	-----	-----	-----	2.0	Tr.	-----	-----	-----	300	316	236	-----	75	95	95
4	-----	-----	-----	-----	2.2	Tr.	46	24	14.0	304	316	244	-----	82	82	[illegible]
5	-----	-----	-----	-----	3.0	Tr.	34	18	9.2	348	324	248	-----	90	75	[illegible]
6	-----	-----	-----	-----	2.5	0.3	40	18	7.6	304	308	240	-----	115	115	[illegible]
7	-----	-----	-----	-----	2.0	Tr.	20	17	8.8	304	304	256	-----	75	97	[illegible]
8	120	28	8.0	16	3.0	Tr.	31	17	8.0	308	312	232	-----	82	80	[illegible]
9	116	84	.0	8	2.5	Tr.	25	19	7.6	304	308	236	-----	90	90	[illegible]
10	96	12	.0	8	2.0	.3	26	17	6.8	296	304	236	-----	95	95	[illegible]
11	68	28	8.0	12	2.0	Tr.	23	20	8.8	296	308	236	-----	70	75	[illegible]
12	148	60	.0	4	1.6	Tr.	18	12	5.6	296	312	228	[2] 18	55	65	75
Average	110	42	3.2	10	2.2	Tr.	29	18	8.5	306	311	239	[2] 18	83	88	[illegible]

[1] Tr. indicates less than 0.1 c. c.

[2] Composite of 9 samples.

TABLE No. 42.—*Results of chemical analysis at the San Marcos (Tex.) sewage-treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.						Dissolved oxygen			Hours to reduce M. B. at 20° ± C.			Nitrogen as—		
	Raw		Effluent septic tank		Effluent final sedimentation tank		Raw	Effluent septic tank	Effluent final sedimentation tank	Raw	Effluent septic tank	Effluent final sedimentation tank	Ammonia		Nitrates effluent final sedimentation tank
	1-day	5-day	1-day	5-day	1-day	5-day				Per cent concentration.			Influent aeration tank	Final effluent	
										10	10	100			
Nov. 3	36	70	24	56	3.5	23.0	4.0	3.1	7.1	144	144+	144+	18	4.8	9.6
4	34	94	18	58	5.3	22.0	3.5	4.9	7.4	96	120+	120+	18	4.8	8.8
5	30	72	20	58	3.3	18.0	3.7	4.4	7.9	120	192+	192+	16	2.2	7.2
6	36	58	24	62	3.5	16.0	1.0	.8	6.7	72	168+	168+	18	2.8	14.0
7	36	80	28	54	3.8	18.0	1.4	2.3	7.5	73	144+	144+	17	4.4	7.2
8	26	52	26	62	2.7	6.4	2.1	2.0	7.6	120+	120+	120+	16	1.4	8.0
9	26	46	26	52	2.8	6.5	1.7	1.6	7.1	96+	96+	96+	17	3.0	5.6
10	----	----	----	----	----	----	1.2	1.8	7.8	72+	72+	72+	18	1.8	8.0
11	----	----	----	----	----	----	3.3	3.2	8.1	48+	48+	48+	18	1.2	8.8
12	----	----	----	----	----	----	6.7	4.9	9.2	24+	24+	24+	17	1.6	11.0
Average	32	67	24	57	3.5	16.0	2.8	2.9	7.6	----	----	----	17	2.8	8.8

The raw sewage was one of the weakest found during the survey. Leaving out the Intrenchment Creek plant at Atlanta, which, at the time of the tests, was receiving considerable storm-water dilution, only the sewage at the Brighton plant at Rochester is comparable with that at San Marcos. These two are almost identical in all the analyses made except alkalinity and chlorine. The differences in the critical constituents are less than might be expected in the daily variations of any sewage.

The septic tank, during the period covered by the analyses, was operating very efficiently. While the removal of 60 per cent of the suspended solids was exceeded at other places, this is high when the total suspended solids in the raw sewage are taken into consideration. The disposal of the tremendous accumulation of sludge produced by the activated sludge process is one of the difficulties of this process. The removal of a considerable part of it in the form of sedimentation-tank sludge by sedimentation before aeration appears to have much in its favor. It is certain that sludge disposal at this plant presents comparatively little difficulty, but whether this is due primarily to the small volume and weak character of the sewage treated and to the large capacity of the septic tank in proportion to the flow can not be definitely stated in the absence of any quantitative sludge data.

The efficiency of aeration, as judged by the reduction of ammonia nitrogen, is high. During the tests the sewage was receiving 1.76

cubic feet of air per gallon. The aeration period was computed to be about three hours with an average flow of 203,000 gallons per day. The ammonia nitrogen was reduced 81 per cent as compared with 90 per cent at the south side plant at Houston, Tex., where the volume of air used was about the same. The two main points of difference between these plants are the presettling at San Marcos and the reaeration of the sludge at Houston. The Houston plant, however, receives much more attention.

The final effluent, as judged by the above analyses, should satisfy the most exacting requirements of sewage-plant effluents. The suspended solids are practically eliminated, and the available oxygen in the form of dissolved oxygen and nitrates and nitrites is more than sufficient to satisfy the entire 5-day demand. It should be noted here, however, that, as it was impossible to do any bacteriological work on the survey, the question of the necessity for bacterial removal could not be included in the studies. The efficiencies of various plants and the character of the effluents had to be judged from the standpoint of potential physical pollution and nuisances in the receiving body of water.

Very little cost data were available. The plant was built by the San Marcos Utilities Co. with their own labor and the final complete cost never computed. Mr. J. E. Wilson, the present manager of the company, estimated that the original cost was about $4,000. This figure is for the activated sludge device and does not include the septic tank which was part of the older disposal plant. Since the plant has been installed in 1916 there has been spent about $300 in modifications and alterations.

Maintenance costs also are not definitely known. It was estimated that one man receiving $150 per month gave about one-fourth of his time, or $450 per year, and that the cost for power was $600 per year. On the basis of these figures, treatment is costing about $14.50 per million gallons. This would be very high for a large plant, but considering the low flow and the character of the effluent, it does not appear so excessive.

XII. SHERMAN, TEX.

The engineering survey of the sewage-treatment plant at Sherman, Tex., was made August 23 to 24, 1920. The laboratory studies followed three months later, November 17 to 27.

Sherman, Tex., is a town of 15,000 population, located in the eastern part of the State, not far from Dallas. It is the center for a large agricultural district, and its activities are centered largely on serving this territory as a collecting and distributing point. With the exception of flour mills there are no industries of any size.

The sewerage system consists of about 23 miles of 6 to 15 inch sanitary sewers. There are no storm-water connections or roof drains, but infiltration and leakage is rather high, at some places excessive. After storms the flow in the sewers becomes so large and carries so much grit that it is necessary to by-pass the treatment plant entirely.

Local topography permits of adequate grades, the minimum for the smaller laterals being 0.5, and for the outfall sewers 0.1 per cent. Ninety to ninety-five per cent of the dead ends have flush tanks connected to the city water mains. These are operated about once every two weeks. In addition, hose flushing with a jet nozzle is done whenever stoppages occur.

There are 1,850 connections serving an estimated population of 7,500, about 50 per cent of the total of the town. In addition, there are two night-soil stations, the main one, serving 1,840 residences, located within 200 to 300 yards of the plant.

All sewage is carried to the plant. as there are no overflows on the system.

The raw sewage is typically fresh domestic. There are no industrial wastes tributary to the sewers except a laundry. While there are no industrial wastes, a large amount of night soil is discharged into the sewers. This frequently is received in an almost unbroken condition, as the main station is very near the plant. A large amount of the paper is caught on the screens, but the sewage entering the tanks is extremely concentrated at times.

No measurements of the sewage flow are made by the city. It was estimated that the flow was from one-half to three-fourths m. g. d. However, during the period covered by the laboratory tests, hourly readings were taken of the outlet weir to the final tank. The average for eight full days was one-third m. g. d. A minimum rate reading of 0.055 m. g. d. was obtained at 5 and 6 a. m., on Thanksgiving morning, and a maximum rate reading of 1.1 m. g. d. occurred at noon of a rainy day preceded by such heavy rains the night before that the plant was by-passed.

Only one-half the plant is in operation, the other half, a duplicate of the one in use, lacks only the air-distribution system to put it in readiness for operation.

The sewage on entering the plant first passes through the grit chambers. These discharge through short channels into the rectangular aeration tank with filtros plate aerators. This tank is divided into three channels in series.

The effluent from the aeration tank passes to the sedimentation tank which adjoins it, separated by a common dividing wall. The outlet of the sedimentation tank is over a weir to the final effluent pipe to Town Branch, a tributary of the Red River.

Sludge drawn from the sedimentation tank is reaerated before entering the aeration tank. Excess sludge is, as a rule, allowed to accumulate in the sedimentation tank until some convenient period of high water, when it is discharged into the stream. The original plans for the plant included sludge drying beds, but these were never built.

The power plant is located in a substantial building of ample size.

There are no laboratory facilities and no analytical work is done.

The personnel at the plant consists of one man who also tends the city incinerator located at the sewage plant. From time to time a laborer is given him for special work.

No attention has been given to the grounds around the plant.

The results of the chemical analyses made at this plant are contained in the following table:

TABLE No. 43.—*Results of chemical analyses at the Sherman (Tex.) sewage-treatment plant*

[Results in parts per million, except as noted]

24-hour sample ending 8 a. m.—	Suspended matter			Settleable solids, 2 hours, c. c. per liter		Oxygen consumed 30′ in boiling water		Alkalinity as $CaCO_3$ by M. O.		Ether soluble matter 24-hour comp., raw	Chlorine as chlorides	
	Raw	Effluent sedimentation tank	Raw supernatant	Raw	Effluent sedimentation tank	Raw	Effluent sedimentation tank	Raw	Effluent sedimentation tank		Raw	Effluent sedimentation tank
Nov. 17	260	34	120	8.0	------	87	22	400	400	86	170	125
18	280	68	100	6.0	2.0	68	30	420	444	63	140	145
19	296	64	84	5.0	.9	58	28	428	440	55	125	140
20	320	144	80	7.0	15.0	79	47	410	410	78	125	140
21	360	100	64	5.5	2.5	58	29	436	432	65	130	120
22	152	50	72	2.0	.3	43	28	430	410	37	135	120
23	252	92	92	6.0	5.0	69	28	440	440	75	110	105
24	224	68	64	4.0	4.0	60	30	420	420	67	135	125
25	320	84	116	5.0	.5	62	48	440	440	91	125	122
26	296	84	104	5.0	4.0	88	48	420	420	98	125	125
27	144	52	44	1.3	.1	30	18	320	320	43	95	95
Average	264	76	85	5.0	3.4	64	32	415	416	69	129	128

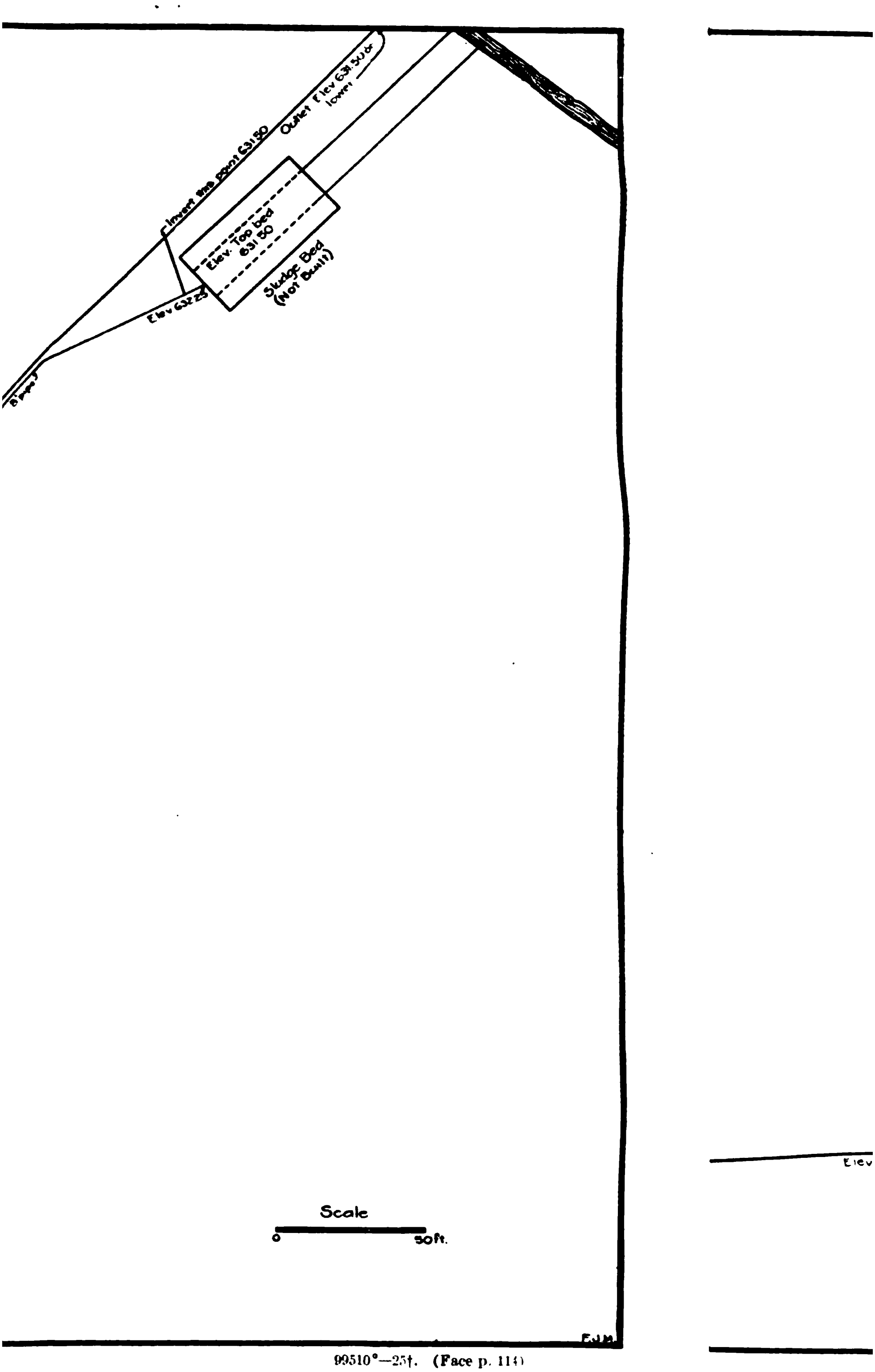


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TABLE No. 43.—*Results of chemical analysis at the Sherman (Tex.) sewage-treatment plant*—Continued

24-hour sample ending 8 a. m.—	Biochemical oxygen demand at 20° ± C.				Dissolved oxygen		Hours to reduce M. B. at 20° ± C.		Nitrogen as—		
	Raw		Effluent sedimentation tank		Raw	Effluent sedimentation tank	Raw	Effluent final sedimentation tank	Ammonia		Nitrates, effluent sedimentation tank
	1-day	5-day	1-day	5-day			Per cent concentration		Raw	Effluent sedimentation tank	
							10	100			
Nov. 17	49	310	6.2	22	5.2	6.4	72	120	------	------	0.8
18	66	230	10.5	48	.0	7.5	48	48	20	26	1.1
19	55	230	13.7	48	1.8	6.0	72	48	22	26	.6
20	77	230	30.0	------	.0	2.1	72	24	24	20	.4
21	49	175	16.5	38	.0	5.8	72	48	28	24	.3
22	33	110	7.8	23	4.7	9.1	168	72	28	26	1.5
23	60	200	13.7	43	2.4	6.9	48	48	26	16	1.5
24	77	180	15.1	44	3.5	6.6	72	24	30	25	1.0
25	44	155	23.0	66	2.2	4.7	48	24	30	25	.8
26	------	------	------	------	3.6	5.8	48	24	32	24	.9
27	------	------	------	------	4.7	7.2	24+	24+	18	22	4.5
Average	57	202	15.2	40	2.5	6.2	------	------	26	23	1.2

The raw sewage is extremely concentrated, one of the very strongest found on the survey. This was due to the dumping of relatively large quantities of night soil into the sewers, most of it within a few hundred feet of the treatment plant. With 1,850 sewer connections and 1,840 residences served by night-soil collection, the sewage should be about double an average sewage in strength. As analyzed, it is very nearly double the average of the sewages studied, and it is not believed that the analyses represent the full strength, because, as the night soil reaches the plant in masses and at irregular intervals, it is doubtful whether a proper proportion of this sewage was included in the composite samples.

While the amount of air used, 4.08 cubic feet per gallon of sewage, was greatly in excess of that used at any of the other activated sludge plants, the efficiency of the treatment as a whole was relatively low. As based on the reduction of ammonia nitrogen, aeration effected very little change. This plant was one of the few which included oxidizing devices that did not effect an appreciable reduction in the alkalinity.

The suspended solids in the final effluent are almost exactly the same as the average for all types of primary sedimentation tanks studied on this survey. The oxygen consumed is even higher. There is a greater reduction in oxygen demand, the dissolved oxygen is high, and there is some nitrification; but, on the basis of the methylene blue test, the available contained oxygen in all forms was in nearly half the samples barely sufficient to satisfy the one-day oxygen demand.

The average dilution in Town Branch, the receiving body of water, is less than one to one, and in dry weather the stream may dry up altogether. Not till the sewage reaches Red River, a distance by stream of about 30 miles, is adequate dilution assured at all times.

It is quite probable, however, that the analyses tabulated represent unusually bad conditions. A short time previous to the laboratory studies, a considerable amount of sludge had been removed, too much, probably, so that the condition of that in the tanks was not normal. In addition the sludge pumps were not operating properly. It is certain that the effluent at the time of the engineering survey was much better than at the time the analyses were made. The fact that since the installation of the plant complaints and damage suits against the city have been dropped is evidence that the effluent is not normally as bad as the analyses indicate. The plant is, however, receiving but little supervision and attention, especially in view of the fact that the sewage, due to the intermittent addition of night soil, is particularly difficult to treat in a plant of this type.

Detailed costs of construction were not obtainable; only the total of $35,000 was available. This figure, of course, includes that half of the plant which is not in use.

The operating cost is not exactly known, but the following are fairly accurate estimates. The total was $3,400 per year, made up as follows:

Regular operator	$1, 200
Extra labor	120
Supplies	80
Power	2, 000

In addition to running the plant, the operator also tends the small city refuse incinerator which is located at the plant. This takes at least half of his time, if not more. Charging this off, the total is reduced to $2,800 or $23.33 per million gallons on the basis of an average daily flow of 330,000 gallons. The power cost is estimated on the basis of the current consumed by a 22-horsepower motor with current at 1½ cents per kilowatt hour.

CHAPTR V

STRUCTURAL FEATURES AND EFFICIENCIES OF THE TREATMENT DEVICES AND PROCESSES STUDIED DURING THE SURVEY

RAW SEWAGE

With the exception of cities served by strictly sanitary sewers, the total volume of sewage is seldom obtainable. Storm overflows carry off a part which is almost never measured and rarely estimated. On some separate sewers this same condition exists.

The average normal or dry weather flow is, however, the important figure for use in the design of a sewage treatment plant. Given this value the plant is designed to handle multiples of this flow, the multiple factor generally being 2 to 3, and the excess is passed around the plant without treatment.

At 13 of the plants visited it was possible to obtain actual measurements of the normal dry-weather flow. At 8 plants it was also possible to obtain fairly accurate information concerning the contributing population. These data are presented in the following table, which also shows the number of connections per capita, the gallons per capita daily of sewage, and the grams per capita daily of oxgen required to stabilize the sewage:

TABLE No. 44.—*Basic data pertaining to sewage*

City	Contributing population (thousands)	Average dry weather flow m. g. d.	Number of connections to sewers	Number of persons per connection	Gallons of sewage per capita daily	Oxygen consumed, 30′ boiling	5-day oxygen demand	Grams of oxygen required per capita daily	
								Basis of oxygen consumed, 30° boiling	Basis of 5-day oxygen demand
Alliance	20	2.62	4,900	4.1	131	38	92	18.8	45.6
Baltimore	520	55	101,000	5.2	106	43	120	17.2	45.1
Canton	70	4.44	15,700	4.5	64	61	213	14.8	51.6
Columbus	225	21.2	41,000	5.5	94	63	190	22.4	67.6
Fitchburg	38	3.35	--------	--------	88	65	155	21.6	51.6
Lexington	28	2.5	4,500	6.2	89	32	144	10.8	48.5
Reading	60	6.04	11,900	5.0	101	45	118	17.2	45.1
Rochester (Irondequoit)	240	33	--------	--------	137	39	104	20.2	53.9
Averages	--------	--------	--------	5.1	101	--------	--------	17.9	51.1
Atlanta (Intrenchment)	[1] 30	[1] 5	--------	--------	[1] 167	35	63	[1] 22.1	[1] 39.8
Atlanta (Peachtree)	[1] 75	[1] 12	--------	--------	[1] 160	35	52	[1] 21.7	[1] 31.5
Houston (north side)	[1] 80	6	} 14,000	[1] 7.1	{ [1] 75	45	116	[1] 12.8	[1] 32.9
Houston (south side)	[1] 20	1.5			[1] 75	38	112	[1] 10.8	[1] 31.8
Rochester (Brighton)	[1] 8	[2] 1.02	1,215	[1] 6.4	[1] 128	24	67	[1] 11.6	[1] 32.5
San Marcos	[1] 2.5	.20	336	[1] 6.8	[1] 80	29	67	[1] 8.8	[1] 20.3
Sherman	[1] 7.5	.33	[3] 1,850	[1] 4.0	[1] 44	64	202	[1] 10.6	[1] 33.6

[1] Rough estimates.
[2] Daytime flow only.
[3] In addition there are 1,840 residences indirectly connected through night-soil disposal.

In the above table the population figures for Atlanta, Houston, Rochester (Brighton), San Marcos, and Sherman are to be regarded as rough estimates. The per capita values derived for these plants indicate a general tendency to overestimate the contributing population or to underestimate the sewage flow.

In estimating sewerage and water supply conditions in localities where population data are not available the round number of 5 persons per connection is commonly used. The average from the data obtained in this survey is 5.1.

The per capita contribution of sewage in the above table varies from 44 gallons per day at Sherman to 167 at the Atlanta-Intrenchment plant. The average value derived from plants where accurate population data were available is 101 gallons per capita daily. This value is affected by many factors, some of which may have little connection with the normal domestic use of water. The amount of infiltration and the general character of the city, whether industrial or residential, are important elements in determining the volume of sewage. Domestic sewage is also subject to variation according to the character and density of the population and the sufficiency of the water supply, the extent to which the individual water services are metered, and other local factors.

The grams of oxygen required per capita daily to satisfy the 5-day oxygen demand of the sewage is given in the last column of Table No. 44. The average value derived is 51.1 grams per capita daily, indicating an ultimate oxygen requirement of about 75 grams of oxygen per capita daily or 60 pounds per capita per year. It is to be noted that this value is somewhat lower than has been previously assumed.

In the 15 plants studied the character of the raw sewage varied within wide limits; at some places, such as Canton and Fitchburg. it was two or three times as strong as at some others, such as the Brighton plant at Rochester and the plant at San Marcos. The following table summarizes the analytical data pertaining to raw sewage:

TABLE No. 45.—*Analyses of raw sewages studied during the survey*

[Results in parts per million except as noted]

City	1-day oxygen demand	5-day oxygen demand	Oxygen consumed, 30' in boiling water	Suspended matter	Settleable solids, 2 hours, c. c. per liter	Ether soluble matter	Ammonia nitrogen	Suspended matter in supernatant	Chlorine as chlorides	Dissolved oxygen	Alkalinity as $CaCO_3$ by M. O.
Atlanta (Peachtree)	15	52	35	226	2.5	83	------	------	86	0.0	68
Atlanta (Intrenchment)	25	63	85	106	2.4	104	------	------	93	.0	78
Rochester (Brighton)	22	67	24	101	2.0	16	------	18	45	3.7	178
San Marcos	32	67	29	110	2.2	18	15	10	88	2.8	306
Alliance	36	92	38	152	2.0	37	------	37	47	3.0	184
Rochester (Irondequoit)	45	104	39	188	2.1	34	------	50	82	.9	175
Houston (south side)	39	112	38	226	2.0	36	18	48	101	.8	304
Houston (north side)	52	116	45	200	2.5	39	17	46	136	.2	270
Reading	62	118	45	145	2.0	25	------	57	120	------	164
Baltimore	59	120	43	159	2.9	40	------	45	86	.2	136
Lexington	65	144	32	166	2.4	58	------	14	89	.1	196
Fitchburg	76	155	65	297	2.7	68	------	56	70	.3	97
Columbus	80	190	63	207	3.1	100	------	60	113	1.7	211
Sherman	57	202	64	264	5.0	69	26	85	129	2.5	415
Canton	118	213	61	261	5.3	62	------	62	79	.5	342
Average	52	121	45	187	2.7	52	19	45	90	1.2	208

In Table No. 45 the various plants are arranged according to the magnitude of the 5-day oxygen demand, and the values presented are averages in all cases. The ammonia nitrogen determination was made only at the activated sludge plants. The table serves to illustrate the range of sewage strength studied during the survey. The 5-day oxygen demand varied from 52 at the Atlanta Peachtree Creek plant, to 213 at Canton, the oxygen consumed varied from 24 to 65, and the suspended matter from 101 to 297 at Rochester (Brighton) and Fitchburg, respectively.

The reason for the strength of the Canton sewage is not apparent. Industrial wastes have been eliminated from the sewers, and, at the time of the engineering survey, no night soil was disposed of in the sewers. This method of disposal was contemplated, however, and may have been started in the interval between the engineering survey and the laboratory studies. At Sherman the strength of the sewage is due to the relatively large amount of night soil entering the sewers. The population is about evenly divided between those contributing through sewer connections and through night-soil collection. At Atlanta heavy rains were encountered at the time of the survey; the indicated values for the strength of the raw sewage are probably much too low.

Any attempt to estimate the relative strength of the raw sewages would necessitate the weighting of the various determinations. In the absence of generally accepted standards of relative merit, the findings would be of doubtful value. If, however, we select as criteria the 5-day oxygen demand, the oxygen consumed, and the suspended matter, it is evident that these three determinations vary concurrently. In this sense the raw sewages presented in Table No. 45 may be said to be arranged in the order of their relative strengths, precedence being given to the 5-day oxygen demand value. The relative position of several sewages which are of nearly equal strength would be altered if the oxygen consumed or the suspended matter were to be selected as a basis of reference; the general sequence, however, would not be materially affected.

The average values given are simple averages, no account being taken of the number of plants falling into each group of possible sewage strengths. They are accordingly valid only if it is assumed that the plants selected for study were truly representative of the general distribution, a circumstance which can not very readily be substantiated. The values, however, appear to approximate very closely to the figures generally assumed as representing the strength of the average American sewage.

It is probable that few municipal sewages are weaker than some of those studied during the survey. In the absence of industrial wastes, the strongest sewages are also well represented. Where industrial wastes form an appreciable part of the sewage, as at Gloversville, N. Y., the strength may be considerably greater than the above table would indicate. Average analyses from other sources are given in Table 46. The values are taken from a table in the 1914 report of the Cleveland sewage-testing station.

TABLE NO. 46.—*Analyses of raw sewages from other sources*

[Results in parts per million except as noted]

City	Oxygen consumed, 30′ in boiling water	Suspended matter	Chlorine as chlorides	Ammonia nitrogen
Chicago	38	141	40	8.
Waterbury	46	106	48	7.
Cleveland	50	252	246	12.
Philadelphia	76	180	30	4.
Akron	86	238	917	4
Columbus	93	215	65	11.
Gloversville	95	406	188	12

Grit chambers.—At plants where sewage from combined sewerag systems or from certain types of industries is treated, it is goo practice to provide means for the removal of heavy inorganic matt such as sand, gravel, etc., before the sewage is admitted to sedime tation or aeration tanks for the removal of organic solids. If carrie over into these tanks, they will cause considerable trouble. In sedi mentation tanks, sludge containing much grit is difficult and a times impossible to remove by normal means, and the heavy solid settle to the bottom and reduce the sludge storage capacity of th tank.

In activated sludge plants, grit carried over to the aeration tanks will either settle and lie over the aerators, reducing the efficiency of this tank, or will necessitate the use of an extravagantly large amount of air to keep it in suspension.

The grit chamber, or detritus tank, is the device commonly used to remove these inorganic solids. In principle, they are designed to pass the sewage at a rate sufficiently low for the deposition of the heavier inorganic solids, but not low enough for the deposition of any large amount of the organic putrescible solids. At Cleveland, Ohio,[1] "It was found that grit which on the average contained more than 15 per cent of volatile matter would be offensive." This per cent of allowable volatile matter will vary with different sewages, but it should be maintained low enough to prevent nuisances when used as a fill.

A velocity of 1 foot per second through the grit chambers and detentions from one-half to one minute are frequently used as nominal figures. At the Cleveland tests, already quoted, it was found that "in general velocities of less than 25 feet per minute do not produce the proper grade of grit and in 25-foot chambers velocities of 60 feet usually carried by some material which should have been deposited." Based on the tests, the grit chambers recommended for this city called for detention periods of 50 seconds, with velocities from 30 to 60 feet per minute.

Metcalf and Eddy state:[2]

> The Rochester experiments with a model grit chamber confirm the general deduction from available experimental information and service experience, that a mean velocity of about 1 foot per second is about right, unless it is necessary to remove very fine and light material, in which case it may be desirable to reduce the velocity and run the risk of some offensive organic matter settling with the grit.

In the design of the grit chambers provision should be madefor the storage of deposited grit. This storage is, of course, dependent on the amount of grit deposited and the frequency of cleaning. It is impossible to give any general figure for the amount of grit removed. The character of the sewage, the geology and topography of the vicinity, condition of streets, tightness of sewers, industries contributing, and other local conditions are all important factors. Data from many operating plants are misleading as it is probable that comparatively few grit chambers are operated at attainable efficiency. Most grit chambers are designed for a definite period of storage between cleanings with an estimated deposition, and errors in these estimates are corrected in operation by changing the period between cleaning.

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[1] Report on tests at sewage testing station. Cleveland, Ohio, 1914.

[2] American Sewerage Practice, Metcalf and Eddy, Vol. III, p. 295.

At most of the plants the grit chambers are cleaned by hand with shovels. At the very large plants, however, there are frequently installed grab buckets, bucket conveyors, or removable containers, some of which are used without interfering with the normal operation of the chamber.

All but two or three of the plants surveyed had some form of grit chamber, though at several they have been remodeled, to serve merely as influent channels. Others because of infrequent cleaning are acting as grit chambers during only a part of the time.

There is so little uniformity in design and operation of this device at different plants that no attempt is made to tabulate structural details and operation data. For such detail of design and arrangement, reference is made to descriptions of the plants in Appendix I.

No analytical work was done to demonstrate the effect of grit-chamber treatment. The only service rendered by grit chambers is the removal of inorganic solids, and it has been shown that this removal is not of such a nature or of sufficient amount to materially affect the suspended matter content of the raw sewage.

SEDIMENTATION TANKS

Plain sedimentation tanks.—The very early sewage-treatment tanks were operated on the plain sedimentation principle, their one and only function being to remove the suspended solids from the sewage, which when removed were transferred to other tanks for digestion or disposed of as fresh sludge. This removal of the sludge was made at frequent intervals, before bacterial decomposition had progressed far enough to produce sufficient gas formation to lift the sludge to the surface of the sewage in the tank. These tanks had, as a rule, flat bottoms and were cleaned by draining off the supernatant sewage, removing the sludge, and flushing out the tank.

Detention periods in this type of tank range from half an hour to six hours, longer periods being considered detrimental, especially where the effluent is to be further treated, as decomposition or septization becomes well established in the sewage if retained too long in a tank. Theoretically, if a sewage contains dissolved oxygen when entering the tank, the effluent will also contain it.

This type of tank was studied only at Alliance, Ohio. Reference is made to the description and discussion of this plant for details connected with its design and operation. No analyses were made of the effluent of this type alone. At Alliance the plain sedimentation tanks were operated in parallel with Imhoff tanks, and the sample of tank effluent analyzed was the combined effluent from both types.

Septic tanks.—This type illustrates the step in the development of sedimentation tanks following the plain sedimentation tank. The

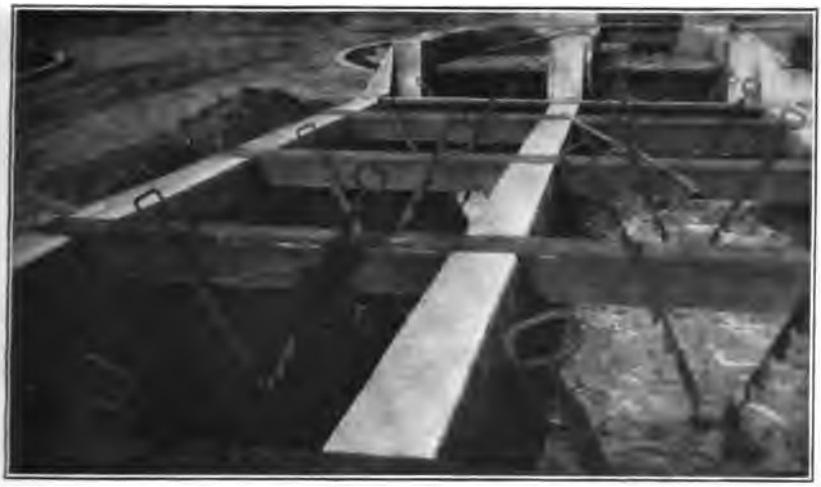

FIG. 25.—GRIT CHAMBERS AT CANTON, OHIO

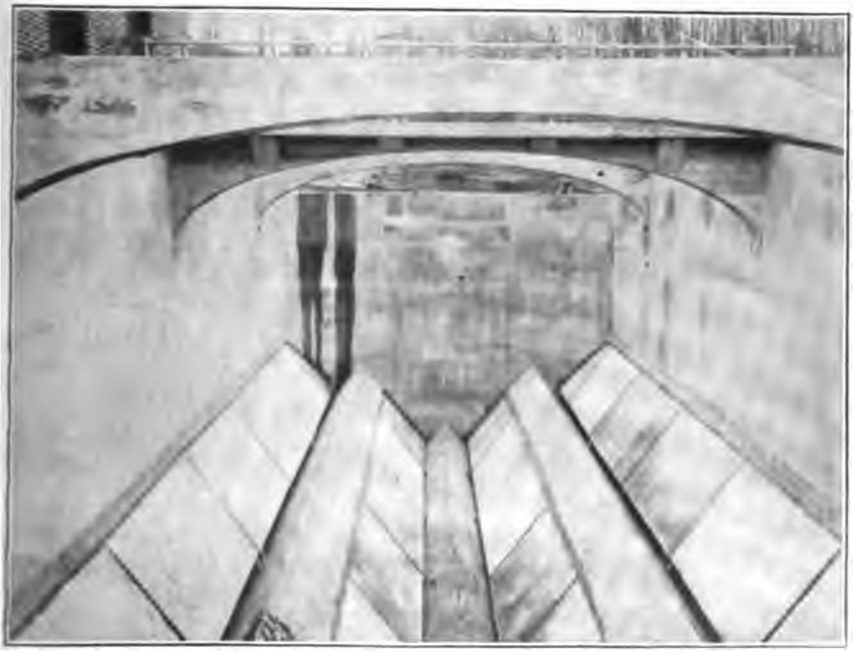

FIG. 26.—INTERIOR OF IMHOFF TANK AT THE BRIGHTON PLANT AT ROCHESTER, N. Y.

most distinctive difference between the two types consists in the operation, whereby the sludge, instead of being removed at frequent intervals, is allowed to remain in the tank and undergo decomposition.

In the operation of septic tanks, the sludge settling to the bottom is attacked by anaerobic bacteria which liquefy some of the solids. This is accompanied by the formation of gas which, entrained in the sludge, lifts it to the surface, where it lies as a heavy scum until the gas is liberated. Then some of this scum may resettle to the bottom. There is, therefore, sludge continually passing up and down through the sewage passing through the tank, some of it washing away with the effluent.

As the bacterial action in the sludge is anaerobic, it was at first considered essential that the tank be protected by an air-tight cover. This is no longer considered necessary, as it is known that the oxygen taken from the air in contact with the sewage at the surface of the tank is used up before reaching the bacterial workhouse at the bottom of the tank.

It was claimed at first that liquefaction of the sludge amounted to 50 per cent of the solids settled in the tanks, and even now it is frequently claimed, for commercial purposes, that this figure is correct or even low, manufacturers of some devices of this type even claiming complete liquefaction. It is now felt, however, that this liquefaction is not more than 30 per cent, and probably less. The apparent larger figure of 50 per cent was due to the fact that every now and then a large amount of sludge is taken up by the sewage as it flows through the tank while the sludge is rising or falling through the sewage, and this sludge is carried out with the effluent. This phenomenon is known as "unloading."

The effluents from septic tanks may be clear and colorless; may have a slight opalescent color due to the presence of hydrogen sulphide, a product of the decomposition of the sludge; or, at times of unloading, may contain fine black sludge in sufficient quantities to give the entire effluent a very dark or black color.

Early in its development the septic tank principle was patented. There resulted from this considerable litigation.

> The effect of this long litigation was to prevent in the United States the development of such favorable opinion of septic tanks as existed in England. This was inevitable when conservative engineers hesitated to involve municipalities in suits in the Federal courts and the engineers who were not so conservative were frequently restrained from risking such suits by the legal advisers of the cities. A large number of tanks were probably built under the name of septic tanks from the plans of persons without adequate knowledge of the principles of sewage disposal, and the failure of these to accomplish the anticipated results and the nuisance caused by some of the worst of them did not help raise the status of this method of treatment.[3]

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[3] American Sewerage Practice. Metcalf and Eddy, Vol. III, p. 17.

The development of the Imhoff tank, discussed elsewhere, offered a relief from the litigation over the septic-tank process, and this type rapidly replaced the septic tank. The Imhoff tank also was patented, but the attitude of the inventor and promoters was such as to win the approval instead of the enmity of American engineers.

With the exception of very small installations the septic tank is very seldom found in this country, though there are some installations made previous to the advent of the Imhoff tank. Many of such installations have been converted into Inhoff tanks, as at Columbus, Ohio, and at others, as Reading, Pa., the officials in charge of the plants are planning such conversion.

Septic tanks were studied on this survey at but two places, Reading, Pa., and San Marcos, Tex. The tanks at these two plants are of such widely different capacity and of such different design that no direct comparison is possible. Reference is made to the discussions and descriptions of these plants in the body of this report and in Appendix I.

Hydrolytic tanks.—This type of tank was studied on the survey at Baltimore, Md. These tanks were operated as plain sedimentation tanks, except that the period between cleanings was sufficient for the formation of a heavy scum and for initial digestion of sludge. Before, however, septic action has progressed sufficiently to materially injure the effluent, they were completely cleaned, the sludge being pumped to separate tanks for digestion.

A discussion and a complete description of these tanks is given under the Baltimore survey and in Appendix I.

Imhoff tanks.—The Imhoff tank is, by far, the predominating type of primary sedimentation tank used in this country. With the exception of the activated sludge plants, all but one of the plants surveyed, Reading, Pa., use these tanks either exclusively or in combination with other types. The city engineer of Reading, moreover, is anxious to convert his septic tank into several Imhoff tanks. Two plants, those at Alliance, Ohio, and Baltimore, Md., use septic and hydrolytic tanks, respectively, in parallel with the Imhoff tanks.

The Imhoff tank is primarily a combination of a plain sedimentation tank and a sludge digestion tank. When these two tanks are operated as separate units, the settled solids, or sludge, are transferred from the sedimentation tank to the sludge tank periodically, before septic action and fermentation has developed to any extent. With the Imhoff tanks this transfer is a continuous operation. The sedimentation tank is built in the upper part of the tank with a bottom opening or slot through which the solids drop from the sedimentation compartment into the sludge compartment. This slot is built so that one side overlaps the other, thus forming a trap to prevent the solids, when buoyed up by gases of decomposition, from reentering the sedimentation compartment. They are instead diverted to sections of the tank, the gas vents, which are separate from the sedimentation compartment.

It is believed that the various types of Imhoff tanks are well represented at the plants surveyed. The radial and longitudinal flow type as well as the shallow and deep types were studied, and most, if not all, of the different arrangements of gas vents were included.

In the following table an effort has been made to tabulate the various salient features of Imhoff tank construction as found at the plants surveyed.

TABLE No. 47.—*Structural features of Imhoff tanks studied*

Plant	Number of tanks	Tank as a whole							
		Shape	Length (feet)	Width (feet)	Overall depth (feet)	Population served (thousands)	Volume sewage treated (m.g.d.)		Reversible flow
							Average	Maximum	
Alliance	2	Rectangular	35.2	60.6	28.5	5.25	0.655	1.12	Yes.
Atlanta (Intrenchment)	21	[1]	31.8	25.0	26.0	[2] 4.29	[3] .714	[3] .856	Yes.
Atlanta (Peachtree)	30		31.8	25.0	26.0	[2] 7.50	[3] 1.2	[3] 1.2	Yes.
Baltimore	28	Circular	39 feet diameter		25.8	3-4	.365	--------	No.
Canton	6	Rectangular	89.0	24.0	22.1	10.0	.74	.94	Yes.
Columbus (Battery A)	8	do	140.7	26.6	27.1				Yes.
Columbus (Battery B)	8	do	126.2	26.6	27.1	10.2	.96	--------	Yes.
Columbus (Battery C)	6	do	117.7	26.6	27.1				Yes.
Fitchburg	5	do	90.0	30.0	25.9	9.25	.76	[3] 2-2½	Yes.
Lexington	4	do	68.0	33.0	28.7	7.00	[4] .60	[5] 1.25	Yes.
Rochester (Brighton)	1	[6]	62.5	30.0	37.0	8.00	1.07	1.86	Yes.
Rochester (Irondequoit)	10	Rectangular	110.0	35.0	40.0	24.00	3.24	5.91	Yes.

Plant	Flow chamber								
	Number per tank	Shape	Length (feet)	Width (feet)	Depth to spring line (feet)	Depth to apex of slot (feet)	Freeboard (feet)	Sedimentation area exclusive of gas vents (sq. ft.)	Cross section at center (sq. ft.)
Alliance	4	Rectangular	35.2	12.2	17.2	14.1	1.75	449	109
Atlanta (Intrenchment)	1	do	31.8	17.8	7.2	14.8	1.25	603	179
Atlanta (Peachtree)	1	do	31.8	20.0	7.2	14.8	1.25	622	179
Baltimore	1	Circular	39 feet diameter		3.5	13.5	.83	973	--------
Canton	2	Rectangular	89.0	10.0	7.5	13.4	1.5	890	89
Columbus (Battery A)	2	do	146.7					1,750	140
Columbus (Battery B)	2	do	126.2	11.8	8.0	15.7	1.9	1,550	140
Columbus (Battery C)	2	do	117.7					1,550	140
Fitchburg	1	do	90.0	26.0	9.1	15.9	1.5	2,185	232
Lexington	1	do	68.0	33.0	7.8	16.0	2.0	2,050	255
Rochester (Brighton)	1	[6]	60.0	24.0	11.0	21.0	2.0	1,440	340
Rochester (Irondequoit)	2	Rectangular	110.0	10.0	10.5	16.5	5.5	1,155	183

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[1] Circular with flow chamber rectangular and overlapping the circular sludge chamber.

[2] Three tanks in series.

[3] Rate, not a 24-hour flow.

[4] Estimated.

[5] Maximum storm rate.

[6] Parallel sides, circular ends.

TABLE No. 47.—*Structural features of Imhoff tanks studied*

Plant	Flow chamber								
	Ratio width to length, 1 to—	Free area gas vents per chamber (sq. ft.)	Gas area of sedimentation area (per cent)	Capacity (thousand gallons)	Volume sewage treated (m.g.d.)		Detention on total disp. hours	Velocity per minute (feet)	Slope of bottom 1 to—
					Average	Maximum			
Alliance	2.9	46.3	10.3	30.9	0.164	0.280	4.7	0.12	1.1
Atlanta (Intrenchment)	1.8	62.5	10.4	42.7	.714	.856	[3] 4.2	.37	1.5
Atlanta (Peachtree)	1.6	43.7	7.0	43.5	[3] 1.2	[3] 1.2	[3] 2.6	.61	1.5
Baltimore		22.3	2.3	63.9	.365		3.8	.06	1.25
Canton	8.9	115.0	12.9	60.0	.37	.47	3.9	.38	1.2
Columbus (Battery A)	12.4	163.0	9.3	118	.48		5.9	.85	1.3
Columbus (Battery B)	10.7	140.0	9.0	108.0	.48		5.4	.78	1.3
Columbus (Battery C)	10.8	142.0	9.1	109.0	.48		5.4	.79	1.3
Fitchburg	3.5	438.0	20.0	185.0	.76		5.8	.26	1.5
Lexington	2.1	156.0	7.5	155.0	[4] .60		6.2	.18	1.25
Rochester (Brighton)	2.5	162.0	11.2	153.0	1.07	1.86	3.4	.29	1.33
Rochester (Irondequoit)	11.0	432.0	28.0	69.4	1.62	2.96	1.0	1.8	1.35

Plant	Flow chamber							Digestion chamber	
	Clearance of slot (inches)	Overlap of slot (inches)	Scum-boards	Baffles	Type inlet	Type outlet	Volume per capita served (gallons)	Shape	Length (feet)
Alliance	7	9	Inlet and outlet.	No	Weir	Weir	23.5	Rectangular	22.0
Atlanta (Intrenchment).	10	7		1	do	do	[3] 29.8	Circular	(7)
Atlanta (Peachtree)	10	7		1	do	do	[3] 17.4	do	(7)
Baltimore	8	8	Outlet	No	do	do	16–21	do	(8)
Canton	6	8	Inlet	Yes	Free	do	12.0	Rectangular	88.0
Columbus (Battery A).	8	10	Inlet and outlet.	No	Weir	do	11.5	do	125.0
Columbus (Battery B).	8	10	do	No	do	do	10.5	do	116.0
Columbus (Battery C).	8	10	do	No	do	do	10.6	do	117.7
Fitchburg	6	3	do	No	Sluice gates.	do	20.0	do	90.0
Lexington	9	10	do	(?)	Weir	do	22.1	do	55.0
Rochester (Brighton).	7	12	do	No	do	do	19.1	(6)	62.5
Rochester (Irondequoit).	9	11	do	No	do	do	5.8	Rectangular	110.0

[3] Three tanks in series.
[4] Estimated
[6] Parallel sides, circular ends.
[7] 25 feet diameter.
[8] 23 feet diameter.

TABLE No. 47.—*Structural features of Imhoff tanks studied*

Plant	Digestion chamber								Capacity to overlap of slots (cu. ft.)
	Width (feet)	Depth-slot overlap to bottom (feet)	Hoppers						
			Number	Shape	Least slope of bottom — to 1	Length (feet)	Width (feet)	Depth (feet)	
Alliance	60.59	13	8	Rectangular	2.1	22.9	15.6	5.0	10,500
Atlanta (Intrenchment).	(7)	10.25	1	Circular	2.0	25 feet diameter		6.25	3,040
Atlanta (Peachtree)	(7)	10.25	1	do	2.0	25 feet diameter		6.25	3,040
Baltimore	(8)	12.25	1	do	2.0	23 feet diameter		5.3	3,600
Canton	14.0	7.58	6	Square	2.5	14.0	14.0	2.75	7,600
Columbus (Battery A)	14.8	9.8	7	Rectangular	2.0	18.6	14.8	4.3	13,500
Columbus (Battery B)	14.8	9.8	6	do	2.0	18.6	14.8	4.3	11,700
Columbus (Battery C)	14.8	9.8	6	do	2.0	18.6	14.8	4.3	11,800
Fitchburg	30.0	10.0	3	Square	2.0	30.0	30.0	7.5	13,000
Lexington	20.0	11.08	2	Rectangular	3.0	27.0	20.0	4.5	7,700
Rochester (Brighton)	30.0	14.33	2	½ rectangular, ½ circular.	2.5	30.0	30.0	6.0	17,900
Rochester (Irondequoit).	35.0	21.25	3	Nearly square	2.0	35.75	35.0	8.0	59,500

Plant	Digestion chamber							
	Size of sludge pipe (inches)	Head over sludge pipe (feet)	Water lines		Baffles	Volume per capita served (cu. ft.)	Volume per m. g. d. treated (cu. ft.)	Cubic feet per p. p. m. influent per m. g. d
			Around hopper	Mouth of outlet				
Alliance	8	4	Yes	Yes	Yes	1.0	8,000	53
Atlanta (Intrenchment)	8	6½	Yes	Yes	No	[3] 2.12	[3] 12,800	121
Atlanta (Peachtree)	8	5	Yes	Yes	No	[3] 1.22	[3] 7,600	33
Baltimore	8	5	No	No	No	1.2-.9	10,700	67
Canton	8	3-4½	Yes	Yes	Yes	.76	10,700	41
Columbus (Battery A)	8	4	No	No	Yes	1.31	14,100	68
Columbus (Battery B)	8	4	No	No	Yes	1.14	12,200	59
Columbus (Battery C)	8	4	No	No	Yes	1.15	12,300	59
Fitchburg	8	Airlift.	No	No	No	1.41	17,000	57
Lexington	8	4½	Yes	Yes	Yes	1.1	11,600	70
Rochester (Brighton)	8	5	Yes	Yes	Yes	2.24	16,700	152
Rochester (Irondequoit)	8	5	No	No	Yes	2.48	18,400	99

[3] Three tanks in series. [7] 25 feet diameter [8] 23 feet diameter.

While at four of the plants, Baltimore, Rochester, Brighton, and two at Atlanta, the circular type of construction was found, at only one, Baltimore, is the flow radial. At the other three plants the flow chambers are all of the type found in the rectangular tanks with the sewage flowing across the tank. In these plants the circular construction applies only to the gas vents and sludge chambers. The Baltimore tanks are the only ones in which the direction of flow can not be reversed.

A discussion of many of the details of the above table would be of comparatively little value. There are some points, however, which should be mentioned to explain parts of the table, and others which are deserving of special attention. For the Alliance plant, the table gives the width of the tanks as a whole as nearly twice the length.

This is due to the fact that the width includes four flow chambers. The ratio of width to length for both the Atlanta plants is that for each individual tank, whereas in operation three tanks must always be run in series, which is equivalent to multiplying the stated ratio by 3. This applies also to the Canton plant, though here it is possible to operate the tanks in parallel.

In a general way the table is of particular value in showing the wide variations in the design factors of Imhoff tanks. Lengths vary from 35 feet at Alliance to 141 feet at Columbus. Considerable importance at some of the plants was attached to the depth factor. The effective depth, the total depth less the freeboard, varies from about 21 feet at Canton to nearly 35 feet at both the Rochester plants. At these latter plants the depth factor is credited with some of the favorable operating conditions obtained, such as the absence of foaming. While analytical results, as given later, afford a means of comparison of the efficiencies of different tanks, it is not believed possible to credit favorable differences to any one factor of design or operation, inasmuch as other factors of equal importance introduce differences that can not be eliminated nor compensated for. The character of the raw sewage, the detention period, and velocity of flow are all of sufficient weight to prevent any comparisons.

The per cent of the gas area to the sedimentation area has received considerable attention in connection with the control of foaming. The tendency has been to make this area about 10 per cent of the surface area of the tank or 11 to 12 per cent of the sedimentation area as used in the above table. This percentage is approximated by 7 of the 12 plants listed, and two others are only 3 to 4 per cent below this figure. The remaining three, however, are radically different. At Fitchburg the percentage is twice and at the Irondequoit plant at Rochester three times the average of the first nine mentioned, while at Baltimore it is only about one-quarter of this average.

At Fitchburg but little trouble has been encountered by foaming. Mr. H. B. Allen, chemist in charge, stated that foaming was not considered a problem at his plant. It persists for only two to four days and is readily stopped or controlled by drawing sludge and pushing down scum with a paddle. Experience at this plant has been that a good heavy sludge does not foam, and for this reason he does not use a stream of water to break up scum in a foaming vent in order not to dilute further a light sludge.

At Rochester, Irondequoit plant, the tanks have never foamed except one tank, which on one occasion foamed for 7 to 10 days. The lack of foaming was attributed by Mr. N. A. Brown, special assistant engineer, to the depth of the tanks, the character of the sewage, a dilute well broken up domestic sewage, and the removal by Riensch-Wurl screens of floating vegetable refuse.

At Baltimore during the early stages of operation considerable trouble was experienced with foaming and excessive scum formation, scum forming even in the sedimentation chamber to depths of, at times, 2 feet. The tanks were taken out of service and slightly modified to correct certain hydraulic factors which interfered with operation. They have since been started again and very little trouble has been caused by foaming which when it did occur, was easily controlled by the use of a hose for a few minutes.[4]

Mr. C. C. Hommon, chemist in charge of the Atlanta plants, was of the opinion that gas vent areas are generally designed too large, preferring the tanks at the Peachtree Creek plant with 7 per cent gas areas to those at the Intrenchment Creek plant with 10.4 per cent. Moreover, some of the vents at the Peachtree plant are capped with a metal gas collector and vented through a one-half-inch gas line. These have never given trouble.

All Imhoff plants visited had experienced foaming to some extent. The tanks at Alliance foam at irregular intervals throughout the year. At this plant fresh sludge from plain sedimentation tanks is pumped into the Imhoff tanks weekly. At Canton, also, foaming occurs off and on throughout the year, though more actively in the summer. On several occasions when attempting to relieve foaming by withdrawing sludge, it was found that only sewage flowed from the sludge pipe, and it was necessary to break up and push down the sludge in the gas vents before any could be removed. The tanks at Lexington foamed considerably during the first year of operation, but in the past two years, although they foam occasionally, they have not caused any serious trouble.

Mr. J. F. Skinner stated that the tank at the Brighton plant at Rochester had never foamed. He attributes this to the dilute sewage treated, the method of starting operation, which consisted in first filling the tank with water and gradually adding sewage, the seeding of the tank with well digested Imhoff sludge, and the fact that operation was started in the early spring, March.

At Columbus, Mr. C. D. McGuire stated that the Imhoff tanks started foaming each spring about four weeks after they were put in operation. As the plant is not operated during the winter the tanks are idle from about December to April. In 1920 one set of tanks, which was not put in operation in the spring, started foaming about June 1, with sludge from the previous year, and this foaming continued for three to four weeks. In line with Allen's statement at Fitchburg that his heavy sludge did not foam, McGuire has noted that at Columbus foaming almost always starts in the middle hoppers and that the inlet hoppers are the last to foam.

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[4] Nine Years Operation of Baltimore Sewage Works, T. C. Schaetzle, Engineering News-Record, vol. 87, pp. 50–54, 97–101.

It was practically the unanimous opinion of the operators of the plants visited that permanent relief from foaming could be obtained only by an adequate removal of sludge. At some plants a stream of water or other mechanical agitation is used for temporary relief to control the tanks till sludge beds are available to receive sludge.

With the exception of the Irondequoit plant at Rochester, no tanks give a theoretical detention period, figured on the total displacement of the flow chamber, under three hours, and several give periods of well over four or five. At several plants efforts have been made to determine by dye tests the actual detention period, but these tests have not been sufficiently successful for use as a reliable basis of computation.

The Irondequoit plant at Rochester stands by itself in the above table with a detention period of only one hour. At this plant the tanks are preceded by fine screens, and the dilution in Lake Ontario available for the tank effluent is so large that the extent of purification required of the plant consists in the removal of solids capable of creating visible nuisances on the surface or the shore of the lake.

The average clearance of the slot at the bottom of the flow chamber is 8 inches. One-third of the plants visited had this clearance, one-third were within 1 inch of this figure, and one-third within 2 inches.

The overlap distance of the slot while varying within greater limits, 3 to 12 inches, is in all except three plants within a much narrower range, 7 to 10 inches.

Probably the most important factor in the design of the digestion chamber is the volume to be allowed per capita contributing. It is essential to provide sufficient volume to insure a thorough digestion period. Necessary capacity beyond this point is dependent upon the sludge-bed area available and climatic conditions. For a plant with adequate sludge-bed area and weather conditions permitting of continuous use throughout the year, a storage over a liberal digestion period is sufficient. Where, however, it is necessary to hold sludge in the tanks over the winter months, provision must be made for this additional storage.

With the character of the raw sewage treated at different plants varying within wide limits it is impossible to compare the sludge storage capacity in more than a very general way. In the last column of the table, a comparison is made on an empirical basis, taking into consideration the capacity of the digestion chamber, the average daily volume of sewage contributing sludge, and the average suspended matter content of the influent as determined by analyses made during the survey. The figure given represents the cubic feet of storage per parts per million of suspended matter per million gallons daily.

The factors given by this method reverse in several instances the relative figures given for the volume per capita served. This reversal is well illustrated by the Fitchburg and Lexington plants. Considering the differences in the composition of sewages and the fact that the computations are made on the basis of 1920 operating conditions, five to seven years after the plants were constructed, it seems rather surprising that so many plants should have factors within such relatively narrow limits. Moreover, some of the plants furthest from the most common average are subject to possible correction. It is not believed that the suspended matter results of 106 and 226 parts per million obtained in the sewages at the Atlanta Intrenchment Creek and Peachtree Creek plants, during the period analyses were made, were representative of normal condition. In the case of the Brighton plant at Rochester the tank was designed for future growth and allows for a much higher volume of flow than that actually passing through in 1920. The two Rochester plants were, moreover, intentionally designed with exceptionally large digestion chambers.

The Canton plant represents the other extreme among the plants visited, but the storage here has always been sufficient to produce well digested sludge, and the lack of capacity in the tanks has been offset by the use of large areas for the disposal of sludge. Additional tank capacity will probably be provided in the near future.

It was noted that at plants where sludge disposal was one of the acute problems the operators spoke more of inadequate sludge-bed facilities than of inadequate sludge capacity in the tanks.

The following table contains the average of analyses of the influent and effluent of the Imhoff tanks studied, together with the per cent removal effected by the tanks. The methylene blue stability results are not included as it is difficult to average these properly over short periods. Chlorine as chlorides is also omitted as there is no change effected in this constituent by tank treatment.

TABLE No. 48.—*Average analyses of influent and effluent of Imhoff tanks studied*

[Results in parts per million, except as noted.]

Plant	Suspended matter			Settleable solids, 2 hours c. c. per liter[1]			Oxygen cons. 30' in boiling water		
	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal
Alliance[2]	152	69	55	2.0	Tr.	100—	38	26	[illegible]
Atlanta (Intrenchment)	106	67	37	2.4	0.6	75	35	21	[illegible]
Atlanta (Peachtree)	226	68	70	2.5	.2	92	35	18	[illegible]
Canton	261	93	64	5.3	.3	94	61	38	[illegible]
Columbus	207	79	62	3.1	Tr.	100—	68	46	[illegible]
Fitchburg	297	63	79	2.7	Tr.	100—	65	37	[illegible]
Lexington	166	67	60	2.4	Tr.	100—	32	23	[illegible]
Rochester (Brighton)	101	40	60	2.0	Tr.	100—	24	15	[illegible]
Rochester (Irondequoit)[3]	198	119	40	2.8	.7	70	44	26	[illegible]

Plant	Alkalinity as $CaCO_3$ by M. O.			Biochemical oxygen demand at 20° ± C.					
				1 day			5 days		
	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal
Alliance[2]	184	194	−5.4	36	29	19	92	68	[illegible]
Atlanta (Intrenchment)	78	82	−5.1	25	9.2	55	68	23	[illegible]
Atlanta (Peachtree)	68	69	−1.5	15	8.5	43	52	20	[illegible]
Canton	342	343	−0	118	80	32	213	120	[illegible]
Columbus	211	219	−3.8	80	61	24	190	134	[illegible]
Fitchburg	97	99	−2.1	76	49	36	155	95	[illegible]
Lexington	196	194	1.0	65	37	43	144	87	[illegible]
Rochester (Brighton)	178	189	−5.6	22	11	50	67	36	[illegible]
Rochester (Irondequoit)[3]	175	190	−8.6	42	30	29	100	74	[illegible]

[1] Tr. indicates less than 0.1 c. c.

[2] The tank effluent analysed included effluents from plain sedimentation tanks operated in parallel with the Imhoff tanks.

[3] Influent is raw sewage after passing Riensch-Wurl screens.

The main function of any sewage tank is the removal of suspended matter. With the exception of Alliance where the samples analyzed were 50 per cent effluent from plain sedimentation tanks, and of the Intrenchment Creek plant at Atlanta where operating conditions were probably affected by abnormal weather conditions, and of the Irondequoit plant at Rochester where the detention is abnormally low and where the sewage was passed through Riensch-Wurl screens before entering the tanks, all tanks effected a removal of suspended matter of 60 per cent or over. The exceptionally good work of the tanks at Fitchburg is probably due to some extent to the amount of grit carried by the sewage. This naturally settles out readily and, it might be added, can cause considerable trouble in the tanks as experience at Fitchburg has demonstrated. On the basis of settleable solids only two plants gave efficiencies of less than 90 per cent.

A comparison of the reduction of the permanganate oxygen consumed with that of the 5-day oxygen demand is interesting in that the percentage of reduction of 5-day demand is, at 7 out of the 9 plants, greater than that of oxygen consumed. It has been held that the removal of suspended matter affected the oxygen demand to a much less degree than the oxygen consumed. This, however, is not borne out by the above table.

Speaking generally, of all the Imhoff tank installations studied, it can well be said that they satisfactorily accomplished their purpose. At all the plants where they constitute the preliminary treatment for filters, the effluents are properly prepared for this secondary treatment, and in the one plant, the Irondequoit plant at Rochester, where they constitute final treatment, the effluent produced is capable of disposal without nuisance in Lake Ontario. At this plant, however, the detention period is too short and velocity of flow through the tanks is too great to effect removal of the lighter suspended matter.

Table No. 48, taken with Table No. 47, suggests a number of points where comparison can be made between various factors of design and efficiency. In a broad way, however, such a comparison raises a question as to the value of refinement of minor features of design in improving the character of the tank effluent. The two tables show that in spite of great variations in design factors and in the character of the raw sewage, the tanks produce effluents of a fairly standard quality so far as the design or operation of subsequent treatment devices is concerned.

Secondary sedimentation tanks.—Under the discussion of trickling filters, mention is made of unloading periods during which solids accumulated and worked over in the beds break loose and are carried out with the effluent. To prevent these solids from reaching the receiving body of water it is common practice to install sedimentation tanks following the filters.

Such tanks are in operation at Baltimore, Md., Fitchburg, Mass., Lexington, Ky., Reading, Pa., and the Brighton plant at Rochester, N. Y. They were also built at Columbus, Ohio, but in recent years have not been used, the filter effluent being by-passed around them.

At Fitchburg they are circular, of the deep, vertical flow, Dortmund type, but at all other places they are the rectangular, shallow, horizontal flow type. The following table contains some of the structural features of these tanks at the plants surveyed:

TABLE NO. 49.—*Structural features of secondary sedimentation tanks studied*

	Baltimore, Md.	Columbus, Ohio.[1]	Fitchburg, Mass.	Lexington, Ky.	Reading, Pa.[2]	Rochester (N.Y.) Brighton plant
Number of tanks	2	2	4	2	4	2
Length (feet)	272	240-340	[3] 30	221	96	11
Width (feet)	280	307	[3] 30	11	100-110	3
Average depth (feet)	10-12	4-6	24	5.7	3-5	2-4
Tank capacity each tank (thousand gallons)	5,700	[4] 3,400	[5] 57	[5] 55	300	75
Sedimentation area (sq. ft.):						
Total each tank	76,180	89,000	640	2,450	10,000	1,4
Per m. g. treated	2,764	8,900	760	2,000	6,670	6,2
Per acre filters	[6] 5,077	17,800	1,280	2,450	10,000	6,

[1] These basins not operated.
[2] The four tanks are slightly different. All fall within dimensions given.
[3] Diameter.
[4] Approximately for two basins averaged.
[5] Exclusive of sludge hopper.
[6] Figured for total filter installation, though all filters are never in use at any one time.

The unit quantities of sedimentation area available per m. g. treated are computed on actual operation data and not on the designed capacities of the filters. Thus at Baltimore the average filter rate, if all filters were operated, was about 1.8 m. g. d., while at the Brighton plant at Rochester it was 1.1.

Comparison of the survey analyses of the effluents of these tanks would give no idea of their relative efficiency, because they cover too short a period. Tanks of this type function primarily when the filters are unloading. At such times their sedimentation efficiency may be high, but at other times, while solids are being stored in the filter these tanks serve no useful purpose, the influent and effluents being almost identical, or the effluent may even be worse than the influent.

A table showing such analytical results is not, therefore, included. They may be found in the analytical tables under the various plants.

FILTERS

Trickling filters.—For the process of oxidation, the trickling filter holds at the present time the center of the stage. While special conditions may indicate other devices at some places, none are equal to the trickling filter for a combination of efficiency, economy, and capacity to stand abuse.

"The trickling filter is a bed, usually 5 to 10 feet deep, of coarse material such as clinkers, gravel, or broken stone, through which the sewage trickles in thin films."[5] It is almost universal practice in this country to apply the sewage to the bed by means of nozzles which act in a manner similar to lawn sprays. Mechanical distributors are used, but these have never gained any popularity in this country.

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[5] American Sewage Practice, Metcalf and Eddy. Vol. III, p. 555.

The oxidation is accomplished by a combination of direct aeration while the sewage is a spray in the air, and of the action of bacteria and other forms of life which grow in tremendous numbers within the bed and which act upon the sewage while passing through the filter. That the direct aeration is but a very minor factor in the process is evidenced by the fact that but little purification is accomplished by these filters until the bacterial zooglea and other forms of life have developed within the bed.

Eight plants using this type of filters were included in the survey. The structural features of these installations are contained in the following table:

TABLE No. 50.—*Structural features of trickling filters studied*

City	Total area (acres)	Ventilators	Rate m. g. a. d.	Average depth (feet)	Rate per cubic foot (gallons per day).	Filtering material	
						Kind	Size (inches)
Atlanta (Intrenchment)	2	Yes	2.5	5¾	10.0	Granite	1½-2½
Atlanta (Peachtree)	2½	Yes	2.0	5¾	8.0	do	1½-2
Baltimore	[1] 30	No	2.7-3	[2] 8½	7.3-8.1	Limestone and trap	1-2½
Columbus[3]	10	No	2.12	5½	9.1	Limestone	1-3
Fitchburg	[1] 2.1	No	[4] 2.7	10¼	6.0	Trap and granite	1-2
Lexington	2	No	[5] 1.75	6	6.7	Limestone and granite	1-2½
Reading, bed 1	1	No	1.6	5	7.3	Slag	1½-4
Reading, bed 2	1	No	1.6	6½	5.6	Feldspar	1-2½
Reading, bed 3	1	No	1.6	5	7.3	Slag	3
Reading, bed 4	1	No	1.6	5	7.3	do	1½-4
Rochester (Brighton)	[1] 1	No	1.6	6	6.1	Dense limestone	1

City	Dosing apparatus	Static head on nozzles (feet)	Nozzles		Lateral distributors	
			Type	Spacing center to center (feet)	Location	Flushing
Atlanta (Intrenchment).	Siphon	8-1½	Merritt	13½	12 inches below surface.	Through nozzles.
Atlanta (Peachtree).	do	8-1⅓	do	13⅓	10 inches below surface.	Do.
Baltimore	Butterfly value.	9±	80 per cent Merritt; 20 per cent Taylor.	15-21	33 inches below surface.	Do.[6]
Columbus[3]	Hand valve	8-4	Columbus, modified.	15⅓	42 inches below surface.	Do.[6]
Fitchburg	Siphon	10-1⅓	Worcester, modified.	15	At surface	Blow-off valves.
Lexington	do	9⅔-2	Taylor (circular).	15	6 inches below surface.	Through nozzles.
Reading, bed 1	do	About 9-2⅓.	Reading	13⅔-15⅓	Bottom	Do.
Reading, bed 2	do	7¼±-2½±	Weand	12½-13⅓	do	Do.
Reading, bed 3	do	About 9-2⅓	Reading	13⅔-15½	do	Do.
Reading, bed 4	do	About 9-2⅓.	Weand	14¼-15½	do	Do.
Rochester (Brighton).	do	6-0	Columbus	14⅓	36 inches below surface.	Blow-off valves.

[1] Entire filter area not used at one time.
[2] Partly submerged, 1½± feet during part of day.
[3] Plant not operated during winter.
[4] 1919.
[5] Estimated.
[6] Can flush direct, but this method not used.

TABLE No. 50.—*Structural features of trickling filters studied*—Continued

City	Underdrains		Extent of control	Pooling	Surface flushing or cleaning
	Type	Flushing facilities provided			
Atlanta (Intrenchment).	Half tile covered	No	Individual laterals.	None	Pick on surface.
Atlanta (Peachtree).	do	No	do	do	Do.
Baltimore	Molded channels covered.	Yes	3-acre units	Little in winter.	Hose on surface.
Columbus[1]	Half tile	Yes, for main collectors.	2½-acre units	Considerable	Pick on surface.
Fitchburg	Molded channels covered.	Yes	Individual laterals.	None	Have broomed surface.
Lexington	Half tile	Yes	½-acre units	do	Nothing ever done.
Reading, bed 1	do	No	¼-acre units	Some in fall, spring, and winter.	Surface raking.
Reading, bed 2	do	No	Individual laterals.	do	Do.
Reading, bed 3	do	No	¼-acre units	do	Do.
Reading, bed 4	do	No	do	do	Do.
Rochester (Brighton).	Sloping bottom to tile.	Yes	Individual laterals.	None	Weeding.

[1] Plant not operated during winter.

At only two plants, those at Atlanta, are artificial arrangements provided to increase natural aeration of the beds. At these there are ventilators with cowls, but the chemist in charge of the plant does not feel that they are of any noticeable benefit. Some other installations have open rubble masonry walls, but there is nothing in the results of these to indicate that any aeration is needed beyond that inherent in the construction of all filters of this type.

The average per diem rate of treatment of the filters studied varied from 1.6 to 2.8 m. g. d. per acre with an average of 2.2. As it is known that the total surface area of the material in the bed is more important than the area of the bed itself, the depth of the bed must be considered. In the table are given the rates in gallons per day per cubic foot of filter material. These rates varied from 5.6 gallons for filter No. 2 at Reading, to 10 for the filter at the Intrenchment plant at Atlanta, Ga. With the exception of these two plants, and at Columbus, Ohio, the variations were between 6.0 and 8.1 gallons per day per cubic foot of filtering material.

At all except two plants dosing is done with siphons. Baltimore uses the butterfly valve and Columbus hand-operated gates. One filter at Reading was equipped with a butterfly valve, but as it was to be replaced in 1920 by siphon, it is credited with this change.

The underdrainage systems are of three types: (1) Sloping flat concrete bottoms overlaid with half tile which may or may not be covered with small slabs or plates upon which the stone rests. (2) The bottoms built with channels molded in them, and the channels covered with small slabs. (3) Bottoms sloping both ways to a drain in the trough of the slopes. This last is probably the simplest and least costly. It was found only at the Brighton plant at Rochester.

At all except two cities, Atlanta, Ga., and Reading, Pa., facilities were available for flushing the underdrains. It does not appear that these have been used very extensively except at one or two plants. However, the chemist in charge at Atlanta stated that such facilities were needed at his plants.

At only one plant was any appreciable amount of pooling observed, but operators at two others stated that they had some in the fall, spring, or winter. At none of the plants had this necessitated, as yet, any appreciable removal of filtering material or much labor on the beds. The surface at some had been loosened with a pick, and at others raking or brooming was practiced, and one plant employed a hose on the surface to flush out deposits.

At nearly all plants a hole was dug into the filters to determine the general nature and prevalence of life. It was not possible to make any detailed study or undertake any differentiation of species, so that no attempt has been made to correlate these observations with filter operation.

At the Intrenchment Creek plant at Atlanta the hole was dug to a depth of 1 foot. The surface stones were of good size with little small material, and clean. Below these there was more smaller stone and all were coated with a slimy mud, but not sufficient to indicate serious clogging. Life was not very abundant. There were very few gray moth flies (*Psychoda*) and the small white worm, usually occurring in small masses, was not observed. The small red spider, while present, was not abundant and there were some few white spiders similar to the red ones. There were also a few long thin red worms.

At the Peachtree Creek plant at Atlanta a 1-foot hole was dug. The top 3 to 4 inches contained considerable deposit, though apparently not sufficient to cause serious clogging. Below this the voids became more open, and, at the depth of 1 foot, were quite free. The filter fly was present, though not prevalent. No small white filter worms were observed. The red spider and some of the larger worms were found, but only in relatively small numbers. The most noticeable feature was the tremendous number of small snail shells. These were seen on the survey in limited numbers in the upper layers of other filters and were frequently present in large numbers in final effluents, but at this plant the top 2 to 4 inches of some sections of the filter was fairly loaded with them. An attendant at the plant stated that he had not found algæ growth prevalent where these shells were abundant.

At Baltimore a hole 2 feet deep was dug in one of the oldest and most used filters, and another about 1 foot deep in a filter used only part of each day. In the first filter the flies and white filter worms were very numerous to a depth of about 4 inches. The red spider was present in fair numbers but not to the extent observed in this same filter four days previous. They were found at depths of 20 inches, but at that depth appeared to be larger than those near the surface. A few angle worms were found below the top 6 inches and a long thin worm, three-quarters to 1 inch long and one-thirty-second inch in diameter. Both of these are probably more prevalent in lower sections as they appear in great number in the effluent. The filtering material was rather compact with small stone filling the voids between the larger stone, but the surfaces were fairly clean, without much slime or other deposits.

In the second filter, life was similar to that described just above, but all forms were less numerous. The spiders appeared, on the whole, to be slightly larger. In two instances these were observed feeding on gray flies, but in other instances the two species seemed to be indifferent to each other's presence.

As noted below, at several other places, extensive web spinning by the spiders had been frequently observed here. No diminution of flies was noted after this had taken place and the formation of webs took place during the day. These points are mentioned as being different from observations at Fitchburg, Mass.

Holes 1½ to 2 feet deep were dug in two filters at Columbus. In both cases the filtering material was found to be badly clogged, one to a depth of 2 feet and the other to a depth of 18 inches where the voids in the stone appeared to become more open. In the more completely clogged filter, life with the exception of the fly, was very limited, only a few spiders and fly larvæ. In the other filter there was more life, but it was not abundant, consisting of the fly to a depth of 4 to 6 inches, some small angle worms, a few spiders, and a limited number of snail shells. From observation at the plant outfall into the river, it was evident that these snails were very prevalent in some parts of the filter. These filters are not operated during the winter, and the assistant chemist, in temporary charge, stated that the white filter worm had not been in evidence since the filters were put on a part-year operation schedule. The spider was, he stated, observed on the surface the first warm spring day before the filters are put in operation. No filter flies are noticed till after two to three weeks of operation. When the filters are operated regularly the spiders seemingly disappear, but if a filter is idle for an hour or two they swarm out on the surface and begin to spin webs, covering the entire bed in a day. If the spiders are very numerous, they have, on hot days, in 45 minutes to an hour, covered with a dense network of webbing the walkway over the filters, which is 500 feet long and 2½ to 3 feet wide.

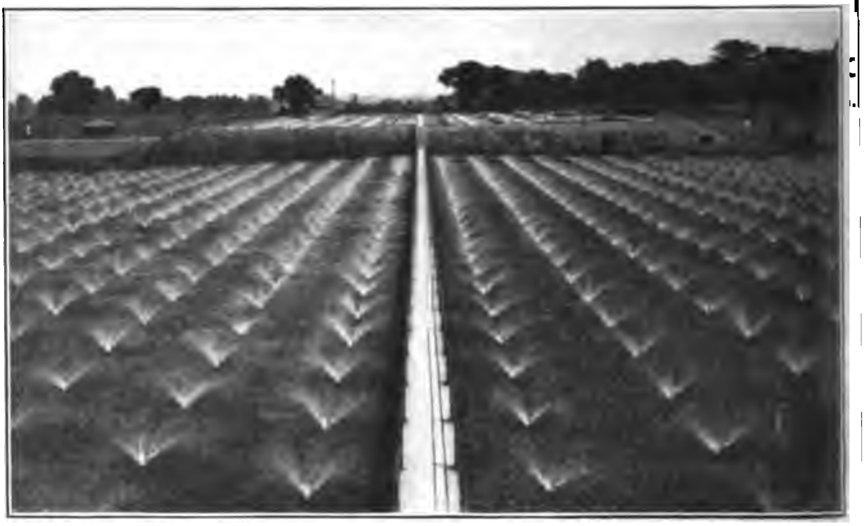

FIG. 27.—TRICKLING FILTERS, WITH IMHOFF TANKS IN BACKGROUND, AT COLUMBUS, OHIO

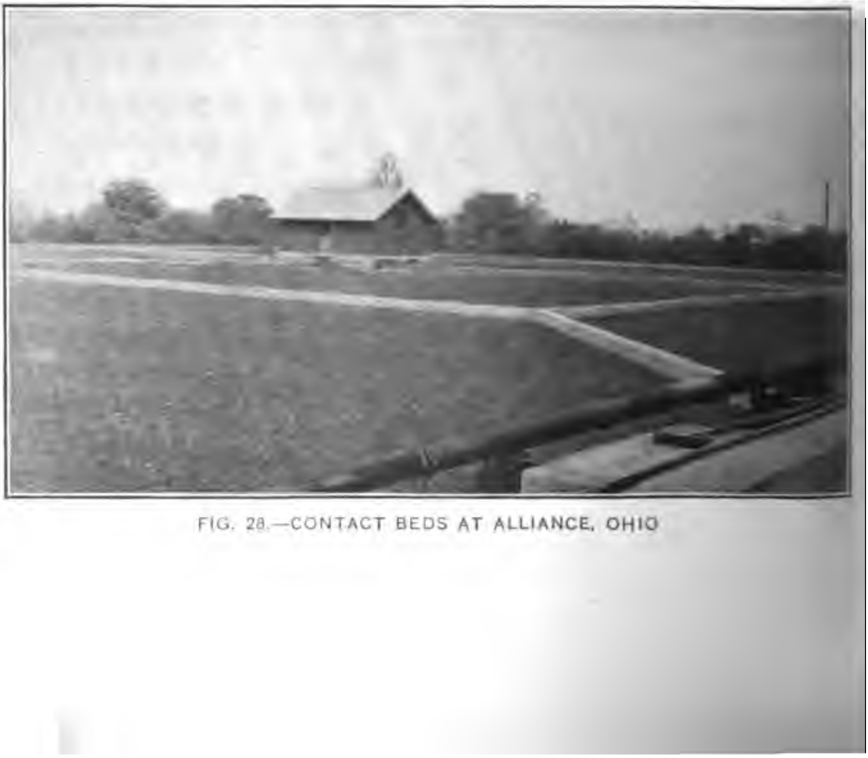

FIG. 28.—CONTACT BEDS AT ALLIANCE, OHIO

No excavation was made at Fitchburg, Mass., but the following information was given by the chemist in charge. The filters were put in operation in October, 1914. During the summers of 1915 to 1917, inclusive, the filter fly was very prevalent, predominating over the red spider. During 1918 and 1919 the flies were more abundant till extremely hot weather in July, when the spiders, working during the night, spun webs covering at times the entire filter area and the grass, trees, and poles adjacent to it. These webs would break loose and float off during the day and be respun in the night. This sometimes continued for two or three weeks. After this, the prevalence of flies was greatly reduced, though both the fly and spider continued to inhabit the beds. At the time of the survey, the latter part of June, 1920, both were seen in the beds, but the flies were not noticeable at any distance from the beds.

In addition to the flies and spiders, the white filter worm was very prevalent, at times spread over the surface of the stones but at other times collected into small masses or balls on the stone. Larger worms, 3 to 4 inches long, are carried off in the effluent but have not been noticed in the upper layers of the filters.

At Lexington two holes, each 12 to 18 inches deep, were dug. The surface stone was largely covered with a layer, about one-eighth inch thick, of greenish black algæ, but there was not enough to cause any pooling or serious clogging. Below the surface the stone was in good condition with the voids open. Life was only fairly abundant, a moderate number of filter flies, some long thin angle worms, a few spiders, and some other forms. None of the small white filter worms were observed.

Because of the differences in medium, construction, and age of the filters at Reading, Pa., shallow holes were dug in all of them. Two slag filters, Nos. 1 and 4, and the stone filter No. 2, all showed more or less surface clogging, the clogging material containing considerable hair. In this clogging material were great numbers of long, thin angle worms to depths of about 6 to 8 inches, the number appearing to be dependent upon the extent of the clogging, with the greatest number occuring in the most clogged filter, No. 4, and the smallest number in the least clogged one, No. 2. Filter No. 3, composed of 3-inch slag, contained little foreign material, and the voids were clear and open. The small white filter worm decreased with clogging, being present in large numbers in filter No. 3 but in relatively small numbers in No. 4 Filter flies and the red spider were found in all filters, the latter being present in great numbers, but the operator stated that he had never seen the extensive web spinning observed at some of the other plants. Some other forms of life, such as slugs, occurred in small numbers.

At the Brighton plant, at Rochester, N. Y., no hole was dug, and only conditions near the surface observed. There was no indication of serious clogging, the voids being well open. Filter flies, earth worms, and the filter worms were all present.

The results accomplished by the filters are shown in the following table of analyses. As with the other devices the methylene blue tests and chlorides results are not tabulated.

TABLE No. 51.—*Average analyses of influents and effluents of trickling filters studied*

[Results in parts per million except as noted]

City	Suspended matter			Settleable solids, 2 hours c. c. per liter[1]		Oxygen consumed 30′ in boiling water			Alkalinity as CaCO^3 by M. O.			5-day oxygen demand			Nitrates in effluent
	Influent	Effluent	Per cent removal	Influent	Effluent	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	
Atlanta (Intrenchment)	67	42	34	0.6	Tr.	21	10.0	52	82	48.0	41	23	4.2	82	1.0
Atlanta (Peachtree)	68	38	44	.2	Tr.	18	7.0	61	69	35.0	49	20	3.9	81	2.0
Baltimore	107	46	57	.6	Tr.	36	14.0	61	144	63.0	56	125	14.0	89	3.3
Columbus	79	81	−2	Tr.	Tr.	46	28.0	39	219	192.0	12	134	40.0	70	.6
Fitchburg	63	52	17	Tr.	Tr.	37	19.0	57	99	7.9	92	96	20.0	79	6.1
Lexington	67	40	40	Tr.	Tr.	22	11.0	50	194	152.0	22	87	[2] 16.0	70	----
Reading	85	48	44	Tr.	Tr.	31	16.0	48	177	105.0	41	96	20.0	79	4.4
Rochester (Brighton)	38	26	32	Tr.	Tr.	15	9.7	35	189	131.0	31	36	7.1	80	2.8
Average	72	47	34	------	------	28	14.0	50	147	92.0	39	77	17.0	78	----

[1] Tr. indicates less than 0.1 c. c.

[2] Effluent secondary sedimentation tanks.

Reductions in suspended matter run from −2 at Columbus to 57 at Baltimore. The Baltimore figure, however, includes removal by the fine screens located between the tanks and the filters. Very little importance can be attached to the amount of suspended matter in trickling filter effluents or the reduction in this constituent effected by them unless results are available for long periods. The amount of suspended matter in the effluent and its ratio to that in the influent will normally vary within wide limits, depending upon the state of the filter as regards unloading. The function of the filter, as regards suspended matter, is not to remove it permanently but to hold it till it has been worked over and oxidized. The character of the solids in the effluent is almost always entirely different from that of the solids in the influent, and it is this change of character that is important.

The alkalinity results are interesting in showing the reduction effected by the filters. An average of 39 per cent was removed. The greatest removal was effected at Fitchburg where the reduction was 92 per cent. This reduction is discussed under alkalinity in the section dealing with the value of various analyses. (Ch. III, p. 11, et seq.)

The close agreement in the relative reductions in oxygen consumed and oxygen demand effected by all the filters is very noticeable.

With the exception of two plants, the reduction in oxygen consumed ranged within the relatively narrow limits of 48 and 61 per cent, and the range for all the plants for oxygen demand was from 70 to 89 per cent. If, as was planned, these filters are representative of their type at sewage treatment plants throughout the country where a reasonable amount of attention is given, they have well earned the good reputation and standing which they enjoy at the present time.

Contact beds.—The contact bed is one of the earliest oxidizing devices, representing "virtually the first logical step in evolving an intense oxidizing machine following plain tank treatment."[6] It consists of a water-tight tank filled with broken stone or other similar material. Sewage flows into the bed, filling the voids in the stone, and is held in contact with the stone for a period called the contact period. During this time much of the suspended solids deposit on the stone, and, in addition, colloids and some dissolved solids are removed by absorption or surface attraction. When the sewage is withdrawn from the bed, these solids are retained in the bed and eventually form on the stones a slimy coating within which great numbers of bacteria develop. As the sewage is withdrawn, air is pulled into the bed and the nitrifying bacteria in the coating on the stone reduce or oxidize the solids deposited.

An illustrative cycle of operation for three doses a day is given by Metcalf and Eddy[7] as follows:

	Hour
Time of filling	1.0
Time of contact	.75
Time of emptying	.25
Time of resting	6.0
Time of cycle	8.0

The requirement for the time of filling is largely to permit the sewage to enter slowly enough to prevent breaking loose the coating on the stone. Some of the solids are removed during the filling. During the contact period the solids and colloids are further removed and the oxygen present in the bed, in the form of nitrates and nitrites in the stone coating, is used up by the sewage. If the contact period is extended after the oxygen is used up, putrefaction will set in to the detriment of the effluent. The time required for emptying is that sufficient to remove the sewage slowly enough to prevent its carrying away with it the deposits in the bed. It is during the fourth, or resting period, that the bacteria in the bed effect most of their work, attacking the deposits left by the sewage. The entire cycle of operation can be made automatic by timing siphons controlling the influent and effluent pipes.

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[6] Treatment and Disposal of Sewage. Hommon, Hoskins, Streeter, Tarbett, and Wagenhals, United States Public Health Service, Reprint 580.

[7] American Sewerage Practice, Metcalf and Eddy. Vol. III, p. 228.

For this type of oxidizing device one-half million gallons per acre per day is generally accepted as an average nominal rate. Gradually the initial rate of a new bed is diminished by the retained solids filling the voids in the stone and reducing the sewage-holding capacity, and eventually the material in the bed must be removed and cleaned.

In this country the use of contact beds is limited, for the most part, to relatively small installations. They frequently are used to avoid pumping the sewage, as the loss of head through them is very little compared with trickling filters. They have an additional advantage of creating less odor nuisance than the trickling filter. For this reason they are selected at some places where the treatment plant can not be well isolated. Their limited capacity, however, together with the necessity of expensive cleaning, has largely eliminated them at the larger plants in favor of trickling filters.

The contact bed installations, at Alliance and Canton, Ohio, were included in this survey. At neither plant are these operated during the winter, both being shut down from about December 1 to May 1. At the time of the survey they had therefore been in operation, for the 1920 season, one to two months.

The following table contains structural and operating data of the contact beds studied:

TABLE No. 52.—*Structural and operation data of contact beds studied*

	Alliance, Ohio	Canton, Ohio
Number of beds	12	16.
Area each bed (acres)	¼	½.
Average treatment rates (thousand g. a. d.).	873	555.[1]
Bottoms	Some all concrete, others only partly concrete.	Concrete.
Nature of material in beds	4 beds have 18 inches slag ¾-1½ inches, 36 inches cinders ¼-⅜ inch; 8 beds have 48 inches cinders ⅛-¾ inch.	Top 5 feet slag ½-1 inch; bottom 12 inches slag 1½-3 inches.
Underdrainage	3-inch tile on 11-foot centers to 8-12 inch collectors.	6-inch half tile on 12-13 foot centers to main drain.
Application of influent	Diagonal duct filled with gravel	Diagonal duct filled and surrounded with gravel.
Control	Automatic	Selection by hand, operation cycle automatic.
Preliminary treatment	Imhoff and plain sedimentation tanks in parallel.	Imhoff tanks.
Filling period (hours)	2½-3 (estimated)	3.
Contact period (hours)	⅓ (estimated)	½.
Emptying period (hours)	2½-3 (estimated)	3.
Rest period (hours)	4½-6 (estimated)	20.

[1] Sixteen beds receive a total of 14-15 doses per day. Operating beds treat 610,000 gallons per acre per dose.

The beds at Alliance are operated at much higher rates than those at Canton. It is probable that they could not maintain so high a rate at Alliance if the operation was continuous throughout the 12 months. They are, during the warm weather months, followed by intermittent fine cinder filters. The beds at Canton were designed to treat a larger flow of sewage than the plant was receiving at the time of the survey, up to 6 m. g. d., or 750,000 gallons per acre per day. It is questionable, considering the strength of the Canton sewage, whether this rate could be attained and maintained for the entire year without seriously affecting the character of the effluent.

Investigations of the condition of the material in the beds gave the following results:

At Alliance several holes were dug, varying from 2 feet deep to the bottom of the bed. The top 6 to 8 inches contained much fine material from the cinders, together with considerable muddy deposits, the voids being pretty well filled up. Below this the voids were more open, the cinders being of fairly uniform size below the top 12 inches. It was noticed that the clogging was greatest in the vicinity of the influent duct, decreasing toward the sides of the bed.

The small gray fly was found in the beds. These, it was stated, have never been noticed except in and in the immediate vicinity of the beds. In a hole dug June 3, while a bed was emptying, enormous numbers of red angleworms were found from 6 to 24 inches below the top. Four days later, however, when this hole was reopened and extended to the bottom of the bed only a relatively few of these worms were found. Nor were they found in any great numbers in any of the other three to four holes dug to depths of 2 feet.

At Canton a hole dug near the influent duct showed considerable clogging to a depth of 2 feet, the voids being pretty well filled up with a gritty deposit, probably small particles of slag from the filtering material. Another hole on the edge of the bed, distant from the influent duct, showed very little deposition, the voids being open. No worms or other forms of life were observed. It was stated that in previous years swarms of small white flies hovered over the bed for the first three to four weeks of operation in the spring. These flies were never observed more than 300 feet from the beds and for the most part stayed right on or over the beds. They were worse the first year of operation. None had been seen in 1920.

The analytical results obtained on the survey on the influent and effluent of these beds are given in the following table:

TABLE No. 53.—*Average analyses of influent and effluent of contact beds studied*

[Results in parts per million except as noted]

City	Suspended matter			Settleable solids, 2 hours c. c. per liter[1]		Oxygen consumed 30′ in boiling water			Alkalinity as $CaCO_3$ by M. O.			5-day oxygen demand			Nitrogen as nitrates.
	Influent	Effluent	Per cent removal	Influent	Effluent	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	Influent	Effluent	Per cent removal	
Alliance	69	17	75	Tr.	Tr.	38	26	32	192	167	13	68	20	71	2.8
Canton	93	41	56	0.3	Tr.	38	18	53	343	354	—3	90	22	76	0.3

[1] Tr. indicates less than 0.1 c. c.

As discussed under trickling filters, the suspended matter determination for the short period covered by the analyses is of relatively little importance, as the function of the bed is more to oxidize than to remove solids. Contact beds do not, however, unload to the extent trickling filters do, so that the suspended matter determination is of slightly more significance. The Alliance beds removed a greater per cent of the suspended matter than did those at Canton, but they fell considerably below the Canton beds in the removal of the oxygen consumed. The removals of the oxygen demand constituents is about the same at both places, and the residual demands almost identical. The nitrates in the effluent at Alliance are considerably higher than at Canton

Intermittent sand or cinder filters.—This device was found at only one plant, Alliance, Ohio, where it is used only during the hot summer months and as a finishing process, treating the effluent from the contact beds.

For details of the design and operation of the Alliance filters, reference is made to the descriptions and discussions of this plant. The discussion here is confined to a brief statement of the principles involved and the position of this device in sewage treatment.

The intermittent fine filter is the most complete oxidizing device employed in sewage treatment, and in addition the most efficient clarifier. In operation the sewage is applied to the surface of the filter, usually by flooding from a radiating trough, and passed through the entire bed of sand or other fine material, such as ground cinders or slag. After a dose of sewage has been applied the filter is allowed to drain and rest.

The suspended matter is largely strained out in the upper layers of the filter, and these form here a gelatinous zooglea mat. This eventually clogs the surface and has to be removed. The greatest oxidation is effected by the bacteria in the top 6 to 12 inches of the filter, decreasing by each succeeding foot.

In construction the beds are usually 4 feet deep. The filtering material is desirably as uniform as possible. Underdrains usually laid 3 to 4 feet deep at the upper end and spaced every 30 to 40 feet should be provided.

Filters of this type were originally used as one complete process of treatment, effecting both clarification and oxidation. At the present time, however, they are generally preceded by a sedimentation tank or both a tank and some form of filter. In the latter case they serve, as at Alliance, as a finishing process where an effluent of unusually high quality is desired.

Because of the high cost of construction and operation and the l capacity of these filters their use is restricted to relatively small pla or for use as secondary filters, except where there are available la

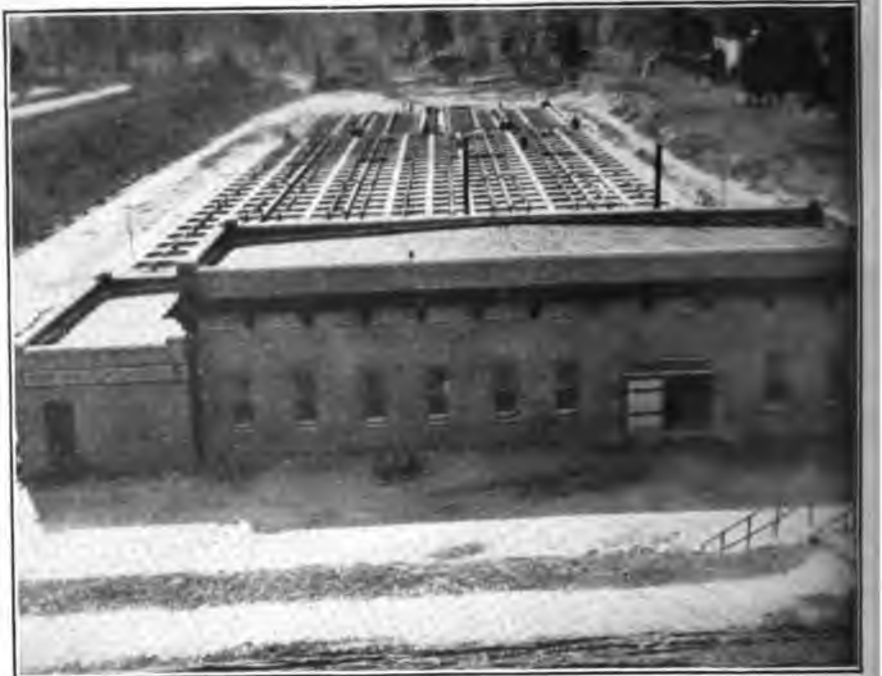

FIG. 29.—THE NORTH SIDE PLANT AT HOUSTON, TEX.

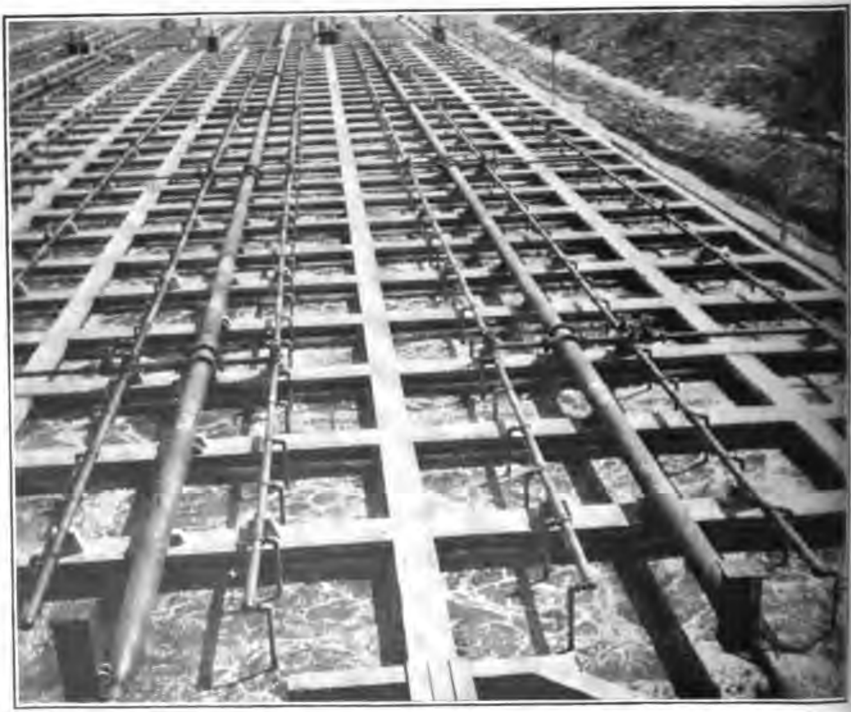

FIG. 30.—AERATION TANKS AT THE NORTH SIDE PLANT AT HOUSTON, TEX.

natural sand areas which can be converted to this purpose with relatively little expense. Such areas are available in many parts of the New England States and along the Atlantic coast, and it is to these sections that extensive use of these filters has been confined.

THE ACTIVATED-SLUDGE PROCESS

The activated-sludge process is the most recent promising development in the treatment of sewage. In "Sewage Disposal," published by George W. Fuller in 1912, no mention is made of this process, though the work of Col. W. M. Black and Prof. E. B. Phelps for the city of New York in 1910 is reviewed. Metcalf and Eddy (1) credit to this work by Black and Phelps the first serious attention in the United States to the aeration of sewage in tanks.

In a bibliography on the subject prepared by J. Edward Porter (2) the earliest reference in American or foreign press is the 1912 report of the Massachusetts State Board of Health. The experiments referred to in this report were largely preliminary to the present accepted process.

Since 1912 many investigators have studied different phases of the process, simplifying it and developing specially adapted apparatus and design features. The credit for the discovery and development of the method has been a subject of considerable controversy. In this connection Kinnicutt, Winslow, and Pratt (3) gave as their conclusions that Dr. G. J. Fowler, of Manchester, England, "to whom is due the actual discovery of the activated sludge process" admitted that "the illuminating idea which originated the work was due to a visit he paid while in the United States to the Mecca of sewage purification, namely, the experiment station at Lawrence, in the State of Massachusetts. Nevertheless, American engineers should reciprocate Doctor Fowler's graceful acknowledgment by recognizing that none of the investigations on this side of the water had really brought sewage aeration to a state of practical usefulness. It was the Manchester studies, and particularly the discovery of the effectiveness of previously aerated or 'activated' sludge in promoting oxidation, which really gave us this important method of sewage purification."

The most elaborate studies in this country have been made by the Sewage Commission of Milwaukee. On the basis of these experiments, this method has been adopted for the sewage-treatment plant at present under construction there. The studies are still in progress.

Large scale thorough tests have been conducted at other cities in this country and in foreign countries. Of those in this country mention should be made of the Sanitary District of Chicago, Ill.; Cleveland, Ohio; Baltimore, Md.; Brooklyn, N.Y.; Champaign and Urbana, Ill.; Houston, Tex.; Massachusetts State Board of Health, and Worcester, Mass. This is not a complete list, but it includes most of the more prominent tests of this process.

The testing station at Urbana, Ill., operated in 1914, is one of the first if not the first exclusively activated-sludge plant in the United States. The city reputed to have built the first plant for the entire sewage of the municipality is San Marcos, Tex., where the Sewer Co. of San Marcos installed a plant in 1915. This plant was one of those studied on this survey. At Houston, Tex., the two largest permanent plants in this country have been operating since 1917. These plants were also studied.

Activated-sludge treatment has been defined "as a biochemical process by which the purification of sewage is accomplished by passing it through tanks, in which sewage sludge is artificially agitated and intimately mixed with sewage and is supplied with the requisite oxygen for the optimum development of countless numbers of nitrifying organisms incoporated in and adhering to the sludge, and the final settlement of which causes a distant clarification of the oxidized sewage." (4)

As is the case with other sewage-treatment processes, the exact nature of the active agents and of the changes involved is not definitely known. Up to the present time study of the process has been devoted largely to the mechanical features of the apparatus used, and to the effect of varying physical conditions of operation. The details of the different physical, chemical, and biological reactions have not been determined. As a matter of fact, this statement is largely applicable to most of the sewage-treatment processes.

A committee on nomenclature composed of Dalyn, Hammond, and Hatton, (4) divided the activated-sludge process into the following treatments:

(*a*) "Economic screening," later defined as "such as may be most economical under the existing conditions. Probably through one-eighth to one-sixteenth inch screen."

(*b*) "Preliminary rapid sedimentation in properly designed grit chambers where combined flow of sewage and storm water must be treated. It is quite essential to prevent detritus of heavy specific gravity, such as sand and gravel, from reaching the treatments which follow." Grit is defined as "that portion of the mineral solids carried in the sewage liquor which will settle out under a velocity of 1 foot per second."

Both of these steps are preparatory to the essential features of the activated-sludge process. The screens may consist of the coarse bar screen with openings 1 inch or more, such as are common to all sewage-treatment plants. In addition to screens and grit chambers, where necessary, a preliminary sedimentation tank may be introduced, as at San Marcos.

(*c*) "Thorough mixing in aerating the sewage with activated sludge, which may be effected by means of air, by mechanical mixers, or a combination of both. In any case sufficient air for oxidation must be supplied to the mixture." Activated sludge is defined as "a flocculent sludge of medium brown color enveloped by masses of aerobic organisms possessing the power of rapidly oxidizing and nitrifying sewage, and which, though of low specific gravity, settles rapidly." It is further stated that activated sludge "must be of such a flocculent character as to absorb the colloidal matter in raw sewage within a contact period of two hours and be of a golden brown color."

(*d*) "Sedimentation of the sludge contained in the admixture as it passes from the aerating tank. This may be accomplished by either horizontal or vertical flow sedimentation tanks."

(*e*) "The return of a portion of the settled activated sludge to the raw sewage before or at the time it enters the aerating tanks."

(*f*) "Reaerating the sludge which is returned to the raw sewage in separate aerating tanks. This may or may not be necessary, depending upon the character of the sewage treated and the effluent required." It can be noted here that this step is omitted at San Marcos, Tex. At this plant the sewage is very weak, but an effluent of very high character is obtained.

(*g*) "Secondary sedimentation for partially dewatering the separated sludge not returned to the raw sewage." In smaller plants where the volume of sewage treated, and, with it, the volume of sludge produced, is relatively small in comparison with the area available for drying or other means of disposing of the sludge this secondary sedimentation of sludge is not essential.

(*h*) "Sludge disposal. This may be effected in several ways. Where the climatic conditions are favorable, it may be dried in beds or lagoons in the open or under cover, and the residue used for filling in low ground, or for fertilizer, or burned. Under unfavorable climatic conditions it may be pressed or centrifuged and burned, or dried by artificial heat and the residue used as a fertilizer."

This brief outline of the process covers the essential principles of the successive steps involved. During the past five or six years many of the details of operation have been studied and some conclusions fairly well established. The process is safely beyond the experimental stage, but probably has not reached its final development. The problem of the disposal of the tremendous volume of sludge produced in excess of that needed for aeration with the sewage is at the present the greatest drawback to the method. This is true of other methods of treatment, but its seriousness is increased with this method because of the greater amount and the character of the sludge produced.

During the survey it was, of course, impossible to undertake any original research into the various steps or processes involved. It was, however, considered to be important to study the method under normal operating conditions. Results obtained under experimental conditions, even where these are on a scale comparable with those to be met in a permanent plant, do not always give a true indication of results to be expected when the supervision and skilled attention incident to experimental work are replaced by normal operating supervision. One of the first criticisms made of the activated sludge method was that it required for successful operation a degree of skill and training not likely to be found in operators at sewage-treatment plants.

The advantages and disadvantages claimed for the method as compared with a combination of methods, such as sedimentation and filtration, producing comparable results may be briefly summarized as follows:

I. Advantages:
  (*a*) The degree of purification obtainable is high.
  (*b*) The area required for the plant is small.
  (*c*) The initial cost of construction is low.
  (*d*) The loss of head is very slight, thus often eliminating the necessity for pumping sewage.
  (*e*) It is odorless (this claim may not apply to the disposal of the sludge).
  (*f*) The sludge produced is higher in nitrogen.

II. Disadvantages:
  (*a*) The volume of sludge to be handled is greatly in excess of that produced by other methods.
  (*b*) The character of the sludge renders handling more difficult.
  (*c*) Operating expenses are high.
  (*d*) There is much mechanical equipment to operate and maintain.
  (*e*) Temporary neglect, resulting in poor sludge, requires considerable time, 10 days to 3 weeks, to remedy, the plant meanwhile producing a poor effluent.
  (*f*) Industrial wastes, especially bactericidal chemicals destroy the purification cycle.

In addition to the above fairly well accepted advantages and disadvantages there are others more or less disputed. The bacterial reduction, found in many instances to be as high as 90 to over 99 per cent, is without doubt a favorable feature, but similar reductions have been obtained with trickling filters, and such reductions are not sufficient in cases where disinfection is required.

George G. Nasmith (5), in a paper before the Engineering Institute of Canada, held that the activated sludge system is unsuitable for small communities or large institutions where an automatic system is highly desirable. This was disputed in discussion by F. A. Dalyn, who had obtained favorable results from several small plants in the Province of Ontario.

R. G. Tyler (6) stated that power costs must be low and at least 1 m.g.d. of sewage treated for this method to be economical for small cities. The limit of 1 m.g.d. would largely limit the method to cities of over 10,000 to 12,000 population.

There are, however, some groundsf or questioning the advisability of emphasizing features of economy and automatic operation in designing sewage-treatment plants for the smaller towns and institutions. In places where sewage treatment is not of sufficient moment to warrant a capable operator, the tendency of entirely neglecting the plant and relying upon the automatic features is too common. Economy in maintenance and operation, which is generally carried to an extreme in small plants, is not real economy.

With the activated sludge process it is conceded at the beginning that the mechanical apparatus requires a daily inspection of the plant. At San Marcos, Tex., this has been sufficient as a routine to insure a very high grade effluent.

There are too many small plants operating at nearly zero efficiency because they are "absolutely automatic," but these plants are not economic successes because they do not cost anything for maintenance or operation. The main expense for the operation of an "automatic" system is labor, but for the activated sludge system it is power. It is easy to reduce the pay or dispense entirely with the services of the labor and still maintain that the "automatic" sewage plant is operating. But dispensing with power at an activated sludge plant is equivalent to abandonment of the plant.

In addition, at small plants the disposal of sludge, which is the big difficulty holding back the adoption of the activated sludge method, is not such a serious problem, even in a relative sense. While the quantity produced per million gallons of sewage may be the same in a small as in a large plant, the total volume is so much less that disposal methods economically impossible at large plants may be perfectly feasible at small plants.

The development of a new process opens an unlimited field for variations of design and operation by different investigators. Up to the present time these have not become standardized, though several details have become fairly well established. In this country, for instance, the weight of opinion is in favor of filtros plates as air diffusers; the principle of continuous flow instead of fill-and-draw is so thoroughly established that only exceptional local conditions justify the use of the latter method of operation.

In the following table, factors of design and operation, so far as they were obtainable, for the plants surveyed are given, and, for comparison, data, more or less complete, on other plants, especially the more recent ones, are included. Much of the information was taken from a digest bibliography on activated sludge by J. Edward Porter (2). Wherever possible the original articles were consulted.

The plants given for comparison do not constitute a complete list of experimental, permanent, or proposed plants. Small test units to study the theory of the process, are not included. Others of comparable importance with some of those listed were omitted because adequate information concerning them was not available.

TABLE No. 54.—*Features of design and operation of activated-sludge plants*

City	Type[1]	Plant capacity, m. g. d.	Ownership[2]	Sewage treated[3]	Preliminary treatment[4]: Grit chambers	Coarse screens	Fine screens	Sedimentation	Aeration tank: Number of tanks	Effective length (feet)	Effective width (feet)	Effective depth (feet)
Houston (north side) (7)	P	[5]10.0	M	N. S.	×	×			4	280	18	9.75
Houston (south side) (7)	P	[5]5.0	M	S.	×	×			2	280	18	9.75
San Marcos, Tex. (7)	P	[6].2	P	S.			×	×	1	145	2.8	12
Sherman, Tex. (7)	P	[6].33	M	N. S.	×	×			2	200	8	12
San Angelo, Tex. (8)	P	[5].4	P	S.				×	1			
Des Plaines River, Ill. (9)	D	3	(7)	S.	×	×	×		4	260	7.6-15	10, 15
Worcester, Mass. (10)	E	.075- .125	M	I. S.	×	×			1	80	4.7	11.5±
Pasadena, Calif. (11)	E	.05	M	S.	×	×			1	60	3	10
Syracuse, N. Y. (12)	E		M	S.	×	×			1	12	4	10±
Champaign, Ill. (13)	E	.144- .216	(8)	S.	×	×			1	105-140	2.2	9.5
Cleveland, Ohio (14)	E	.280- .470	M	S. I.	×	×			4	30	9.3	14.5

City	Sedimentation tank: Number of tanks	Effective length (feet)	Effective width (feet)	Effective depth (feet)	Reaeration tank: Number of tanks	Effective length (feet)	Effective width (feet)	Effective depth (feet)	Operation[9]	Diffusers	Ratio diffusers to surface area, 1 to—	Aeration period, (hours)
Houston (north side) (7).	40	18.8	10	22.8	4	384	3.9	10.8	C	Filt.	7.5	2.7
Houston (south side) (7).	20	18.8	10	22.8	2	384	3-9	10.8	C	do.	7.5	2.6
San Marcos, Tex. (7)	1	20	10	25	0				C	do.	11.4	2.5+
Sherman, Tex. (7)	2	28.4	21.9	15.2	2	230	2	12	C	do.	8.0	[6]2.3
San Angelo, Tex. (8)	1	20	18	25					Day C	Pipe.		
Des Plaines River, Ill. (9).	12	24	24	15±- 19.25	2	260	7.6	10	C	Filt.	5.7 5.9	
Worcester, Mass. (10)	1	14 diam.		20±	1	12	5.3	11.5±	C	do.	5.2	4-6
Pasadena, Calif. (11)	2	16	6		1	12	6	10	C	do.	8.5	4
Syracuse, N. Y. (12)	1	4	4	15±	1	4	4	13±	C	Pipe.		
Champaign, Ill. (13)	1	10.5	6	11	1	36	3.2	9.5	C	Filt.		4-6
Cleveland, Ohio (14)	1	30	9.3	30	1	30	9.3	17.3	C	do.	5	1.1-1.0

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[1] P = permanent plant. E = experimental. D = designed but not built by January, 1921.

[2] I = industrial or institutional. M = municipal. P = private.

[3] I = industrial wastes. N = night soil. S = sewage.

[4] × indicates presence.

[5] Design basis.

[6] As operating.

[7] Sanitary District of Chicago.

[8] Illinois State Water Survey.

[9] C = continuous.

TABLE No. 54.—*Features of design and operation of activated-sludge plants*—Con.

City	Sedimentation period (minutes)	Reaeration period (hours)	Per cent sludge, returned	Air used, cubic feet per gallon	Air factor[10]	Cap. m. g. d. per acre aeration tank	Vol. sewage treated per aeration tank m. g. d.	Method of sludge disposal[11]	Sewage treated per square foot sedimentation tank, gallons	
									Design	Operation
Houston (north side) (7).	60	4	15–25	1.5	110	[5] 22	2	L or T. P. D.	1,330	1,064
Houston, (southside) (7).	70	5.5	20	1.7	124	[5] 22	1.5	L.......	1,330	800
San Marcos, Tex. (7).	60–120	0	....	1.8	112	[6] 15	.2	B.......	....	1,000
Sherman, Tex. (7).	[5] 40	[5] 2.5	....	4.1	307	[6] 8	.3	A.......	....	540
San Angelo, Tex. (8).	....	....	....	....	....	....	....	....	....	1,100
Des Plaines River, Ill. (9).	....	....	....	....	....	9–18	....	C.D.P.T.		
Worcester, Mass. (10).	100–175	3–6.5	16–30	1.7–6.0	128–375	3.5–15	.075–.125	B. P. T.	....	....
Pasadena, Calif. (11).	30	(?)	10–20	1.0	65	12	.05	B. T....	....	500
Syracuse, N. Y. (12).	....	....	....	....	....	....	....	....	....	....
Champaign, Ill. (13).	24–37	....	....	2	160	13–20	....	B.P.D.C.	1,917	....
Cleveland, Ohio (14).	40–67	1.1–4.5	25–34	.74–1.30	80–141	20–75	.28–.48	B.T.P.C.	1,916	....

[5] Design basis.

[6] As operating.

[10] Air factor=products of cubic feet free air per cubic foot of sewage by feet of air submergence. When submerged figure was not known it was assumed to be depth of tank, less 1½ feet free board.

[11] A=dilution into stream; B=beds; C=centrifuge; D=drier; L=lagoons; P=presses; T=concentration tanks.

It is difficult and sometimes impossible to arrange in tabular form data published from experimental plants. The design and methods of operating these plants are so changed and varied during the tests that a correct statement of dimensions and operating factors are possible only with a confusing number of footnotes or explanatory paragraphs. In the following discussion of individual items in the table, data from some plants not listed are included.

PRELIMINARY TREATMENT

Grit chambers.—There is a general agreement among engineers and operators that heavy inorganic solids must be excluded from the aeration tank. Where the sewage, therefore, contains any appreciable amount of grit, grit chambers must precede the aeration tank. Grit in the aeration tanks will either settle over and clog the air diffusers, preventing uniform and thorough agitation and aeration, or will necessitate the use of an extravagant amount of air.

Messrs. Dalhyn, Hammond, and Hatton (4) include as part of the activated sludge process "preliminary rapid sedimentation in properly designed grit chambers where combined flow of sewage and storm water must be treated. It is quite essential to prevent detritus of heavy specific gravity, such as sand and gravel from reaching the treatments which follow."

The elimination of grit as preliminary to sedimentation is well established, but its presence is even more undesirable in aeration tanks than in sedimentation tanks. Of the plants listed above only two are not provided with grit chambers, and these have presedimentation tanks.

Coarse screens.—These, which are considered to include all screening devices with openings larger than one-half inch, are in the same class as grit chambers. They serve to remove large particles which are not amenable to tank treatment, interfere with the aeration process, and admit of more economical disposal if handled by themselves.

Fine screens.—On the value of fine screens there is less agreement. Hatton (15) as a result of the Milwaukee tests advocates the use of fine screens. "We found at Milwaukee we could save from 15 to 20 per cent air when treating a sewage passing a 20-mesh screen as compared with the same sewage passing a 1-inch grid screen." He also found it helped smooth plant operation. The reasons for the fine screens may be, however, largely local. "The character of sewage produced in Milwaukee creates in the aerating tanks large masses of hair, lime, entrails, leather findings, pieces of hide and back; these are constantly deposited upon the surface of the diffuser plates, interfering with their efficiency and stopping up the orifices to sludge pumps." (15) Where a purely domestic sewage is to be treated by the activated-sludge process, the author, Hatton, is not so sure that such fine screening is necessary. He believes that a three-sixteenth-inch slotted screen is fine enough for any sewage.

Pearse (16) concluded from his experiments at the Chicago Stockyards that "the use of the fine screen (20–30 mesh) seemed advisable to remove much comparatively inert material which is slow to oxidize. The runs made with a screen did not appear to differ greatly in character of effluent from those without. The coarser material, however, deposited in various undesirable places, when the screen was not used, and additional air was required to keep it in suspension." These conclusions apply to the treatment of stockyard wastes, but the design for the Des Plaines River plant prepared by and under the direction of Mr. Pearse and treating domestic sewage provides for fine screening.

G. B. Gascoigne (17) questioned, from the results obtained at the Cleveland activated sludge testing plant, the necessity or economy of fine screens. The sewage treated at this plant, while fairly strong, has its solids in finely divided state as a result of long travel in the outfall sewer.

None of the plants visited on this survey had fine screens with the exception of San Marcos, which has a one-fourth-inch mesh over the outlet pipe of the septic tank which precedes the aerating tanks. Other plants in this country and abroad, both experimental and permanent, are operated for the most part without fine screens.

The advisability and economy of fine screens as preliminary treatment to the activated-sludge process does not appear to be definitely proved, at least not for universal application. For large installations and when the solids, especially those from industrial wastes, are large, the fine screens may pay for themselves. But it is questionable whether their installation would be an economy at the average plant treating domestic sewage.

Preliminary sedimentation.—This has not been considered favorably by many investigators. The activated-sludge process has been viewed as a complete process in itself, performing the functions of both clarification and oxidation or, as at Cleveland, only clarification. With the ability of the process to perform both of these functions once well established, investigation has turned to the disposal of the by-product, the large amount of sludge. This sludge is, for sewage sludges, so relatively high in nitrogen that the development of an economically practical method for utilizing the value of this nitrogen in the disposal of the sludge has been the object sought by most investigators.

With this idea foremost, the use of preliminary sedimentation has been discounted. Hatton stated (15):

> Preliminary sedimentation, in lieu of fine screening, is not applicable to the activated-sludge process if the sludge is to be disposed of finally as fertilizer. The sludge from such a tank contains very little ammonia, is hard to handle and mix with activated sludge, and when mixed adds to its weight without adding correspondingly to its value; whereas, fine screenings contain almost as much available nitrogen as the activated sludge, can be easily mixed with it in the dryer, and increase the value of the mixture to a proportionate extent.

While many experiments have been encouraging, giving promise of economic methods of disposing of surplus activated sludge as a filler or fertilizer with a revenue at least equal to the cost of handling the sludge, and possibly more, there is, at this time, no activated-sludge plant actually disposing of its sludge through this channel.

The majority of the permanent plants at present operating in this country are small, and produce too little sludge to justify the installation of an expensive plant for its preparation as a fertilizer base. For plants of this size the use of a preliminary sedimentation tank to remove most of the settleable solids before aeration, and possibly to serve as a digestion tank for excess activated sludge, is worthy of consideration. By this tank the sludge would be prepared for drying on beds and the total volume to be handled greatly reduced. With such an arrangement the aerating tank practically replaces a trickling filter or other oxidizing devices.

AERATION TANKS

After the period of retention in the aerating tank and the volume of liquor to be treated are decided, the tanks should be so proportioned as to give the greatest length of flow possible without wasteful use of piping and concrete. (15.)

The predominating shape of aeration tanks is long and narrow. In many, the length is obtained by longitudinal baffles diverting the flow back and forth two to four or five times. Of the plants listed in the preceding table the ratio of width to length varies from 1 to 3 to 1 to 38, taking in the extremes represented by the experimental unit at Syracuse, N. Y., and the permanent plant at San Marcos, Tex. The two plants at Houston and the one at Milwaukee have the same ratio, about 1 to 15.5 With the exception of the small experimental tanks at Syracuse and the one at Cleveland, which latter was designed for clarification only, the ratio of 1 to 15.5 is the lowest of any plant listed in the table.

Some tests have been run with circular tanks at Baltimore, Md., where an existing Imhoff tank was used, at Milwaukee during the early tests, and other places, but the opinion now is predominantly in favor of rectangular tanks.

In the above table the Milwaukee tanks provide the greatest effective depth, with those at Cleveland only 6 inches shallower. This depth was adopted at Milwaukee as a result of tests made with a 10-foot and a 15-foot tank run in parallel. Eddy, Fales, Copeland, Ferebee, and Hatton (18), on the basis of the results obtained reached, among others, the following conclusions:

There was a slight difference in favor of the 15-foot depth of tanks, not taking into consideration the extra cost of compressing the air for a 15-foot depth of liquor over that for a 10-foot depth.

The Sanitary District of Chicago (19), in designing the Des Plain River plant, provides both 10 and 15 foot aerating tanks to te the relative efficiency of these depths for the local conditions there For the most part the depths at the other plants are fairly clo to 10 feet.

The use of filtros plates as air diffusers is well established in th country. Some investigators have obtained good results wit perforated pipe, but where these have been tested in parallel wi porous tile, wood blocks, and filtros plates, the almost unanimo verdict has been in favor of the last named. Among the mo important studies of diffusers were those made by Hatton and Copeland at Milwaukee and Bartow at Urbana.

A number of mechanical agitating devices have been tried an with varying success, but none has received any general recog- tion as a substitute for the air agitation with filtros plates. Th offer a possible field for future development. It has been demo trated that only a small per cent of the air used in the aeration nks is necessary for the oxygen taken up by the sewage, and that e bulk of the air is of value purely for agitation. Haworth (20) described a mechanical agitator used in tests at Sheffield, England. Surface absorption was the only source of oxygen for the sewage. The question is largely one of efficiency and economy, with the best vidence so far in favor of air diffusers as against mechanical gitation.

The ridge and furrow or saw-tooth bottom is almost standard for plants in which the aerating chamber is wide enough to provide for two or more filtros plates. The hopper bottom, each hopper containing one plate, is a modification of the ridge and furrow bottom, the main idea being to confine all flat-bottom surface upon which sedimentation is likely to occur to the area occupied by the filtros plates. The slopes on the ridges should be adequate, 1 to 1, or to 1.5, to prevent any accumulation of sludge. Some good results have been obtained in tests with flat-bottom tanks using mechanical devices to prevent sedimentation of sludge, but their use so far has been decidedly the exception.

The ratio of air diffusers to tank surface as given in Table No. 54, shows fairly wide variation. Hatton (15) stated: "The economical ratio depends largely upon the type of aerating tanks used and the character of effluent required." In 1917 he had designed the Milwaukee permanent tanks on a 1 to 6 ratio, but as a result of subsequent experiments changed to 1 to 4.5. The Cleveland experimental units in 1916 were designed with a 1 to 5 ratio in spite of the fact that clarification only was sought. For the most part the ratios are higher, running around 6 to 8. The San Marcos plant with a ratio of only 1 to 11.4 produces an exceptionally good effluent, but the sewage is very fresh, unusually weak, and is presettled before being aerated. In England the ratios run lower than in this country, two plants at Manchester having ratios of 1 to 10 and 14.

The capacity of the tanks, upon which the aeration period largely depends, is generally designed to give aeration periods, on a total displacement basis, of from 2½ to 8 or 10 hours, for sewages, and longer, up to 20 hours where there are large amounts of industrial wastes. From results obtained in the Milwaukee tests, Hatton, Eddy, Fales, Copeland, and Ferebee (18) agreed that "with properly baffled tanks, 4 hours on domestic sewage would probably be all that was required." For Milwaukee, the units designed provide for 6 hours aeration under normal flow. This is for operation without reaeration of the sludge. Pearse (16) found at the Chicago Stockyards that during the same period of the year he obtained about the same results with 9-hour aeration without reaeration as he did with 6.6 hours aeration with reaeration. In the test at Cleveland, Pratt and Gascoigne (14) report aeration periods as low as 1.1 hours where reaeration was used, but in these tests clarification was the main result sought. As a result of their tests they concluded that an average of 3 hours would accomplish the results desired. Three and one-half hours is sufficient at San Marcos to produce a highly oxidized stable effluent from a weak, fresh, presettled sewage.

While 6 hours is a fairly representative figure to use in general discussion, it may vary considerably both ways, depending upon the character of the raw sewage, the degree of purification desired, the temperature, the amount of sludge returned, and the volume of air used.

It has been found in comparative tests that an 8-hour aeration period requires only about half as much air as a 4-hour period. Air is used for two purposes, first, to provide oxygen required for the reduction of the organic matter in the sewage, and second, for agitation. The amount of air necessary is determined by the latter requirement, as only a very small part of the available oxygen in the air is used by the sewage. Crawford and Bartow (21) found the oxygen used by sewage to be 5 per cent of that available, and Eddy (22) found only 10 per cent of the oxygen disappearing from the air used with strong tannery wastes.

Eddy (22) gives, as a general statement—

> Where aeration is carried out in continuous flow tanks of 10 to 15 feet depth, with area of diffuser plates in proportion of 1 to 6 of tank area and a period of agitation of about 6 hours, the quantity of air may be about as follows:

	Cubic feet per gallon
For rather weak domestic sewage	1.0
For strong municipal sewage containing considerable industrial wastes not particularly detrimental to bacterial life	1.5
For weak municipal sewage containing considerable industrial wastes some of which are detrimental to bacterial life as, for instance, acid iron wastes	2.0
For strong municipal sewage containing considerable industrial wastes some of which are detrimental to bacterial life as, for example, acid iron wastes	4.0
For municipal sewage containing sufficient industrial wastes not specifically inhibitive of bacterial life to decidedly influence the composition of the sewage, e. g., packing house, tannery, etc	3.0
Strong packing house waste	4.0
Strong tannery wastes containing a very large proportion of colloids but settled before aeration	6.0

In the majority of activated plants provision has been made for the aerating alone, or the reaerating, of the sludge before its addition to the raw sewage. The reaerating tanks are generally of similar construction to the aerating tanks, though this is not essential. Unless special provisions are made for air control, however, the depth of the two tanks must be the same or the air will take the path of least resistance through the more shallow tank.

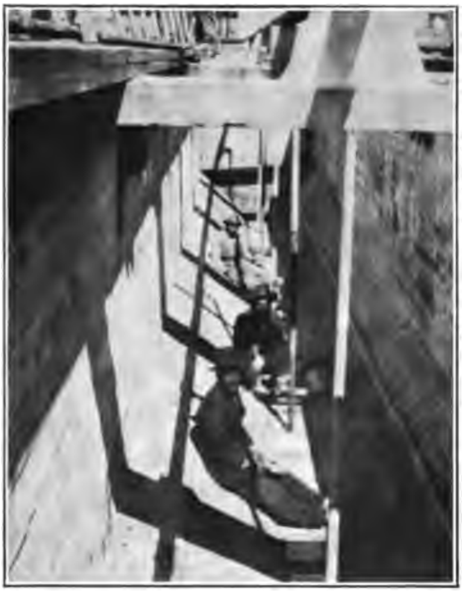

FIG. 31.—INTERIOR VIEW OF REAERATION TANK AT THE NORTH SIDE PLANT AT HOUSTON, TEX.

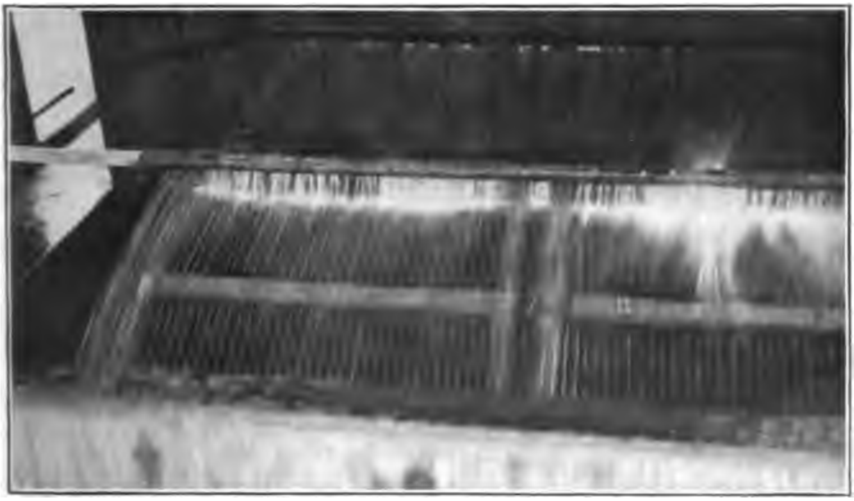

FIG. 32.—FINE SCREENS AT BALTIMORE, MD.

REAERATING TANKS

There is some difference of opinion regarding the value of reaerating sludge between its removal from the sedimentation tank and its addition to the raw sewage. Hatton (18) is not including reaeration tanks in the design of the permanent Milwaukee plant.

> It is hoped that by reaerating the sludge the aerating capacity might be reduced, due to a richer sludge, but our experiments indicated that this was not a fact, at least to the extent of warranting us in providing extra tankage and air for reaeration.

On the other hand Pearse (16) reports a probable saving of 20 per cent of tank volume by reaerating together with a reduction in the period of aeration and a slight saving in air consumption. At the Des Plaines River plant of the Sanitary District of Chicago (19) provisions are made to test the value of reaeration for local conditions and the tanks are so designed that with minor modifications they can be included or omitted.

Three of the four plants studied on the survey employed reaeration. At Houston one-third of the air was used in this tank and the detention period was over twice that in the aeration tank. At Sherman the sludge was reaerated, but there were available no data regarding the operation of the reaeration tank. At San Marcos reaeration was omitted.

SEDIMENTATION TANKS

On leaving the aerating tanks the sewage with the contained activated sludge passes to sedimentation tanks for separation of the sludge from sewage.

These tanks must provide a detention period long enough and surface area adequate for the sludge to settle; must have sufficient depth to prevent the sludge being carried out with the effluent; and must provide means for the removal of sludge.

The detention periods as given in Table No. 54 vary from 24 minutes at Champaign, Ill., to nearly 3 hours at Worcester. Hatton (15) stated in 1917, "the detention period may be from 30 to 50 minutes according to the character of the sewage." From later tests he concluded that to obtain concentration at least 1 hour should be allowed for settling and that the maximum velocity of flow should not exceed 1.5 feet per minute. Pratt and Gascoigne (14) tested periods as low as 35 minutes without claiming to have reached the lower limit. The corresponding velocity was 1 foot per minute. While the shorter periods are effective under normal conditions, the effect of operation during cold weather or with underaeration is to produce a voluminous fluffy sludge requiring longer periods for renewal. Alvord, Eddy, and Fuller (23) placed 1 hour sedimentation under maximum flow as basic.

Considerable attention has been given to the depth of the sedimentation tanks. The Milwaukee tests indicated for local conditions a minimum requirement of 15 feet. Because of the lightness of the sludge it is very susceptible to changes in the rate of flow, and the volume occupied by the sludge is dependent on its condition. The data at present available indicate a minimum depth of 15 feet. For the most part the sedimentation tanks have been deeper in order to provide hopper bottoms for concentration of the sludge to the point of removal. The slopes on these hoppers must be steep to prevent deposition and septic action. Pearse (16) found that, to prevent this, the slopes should be about 2 vertical to 1 horizontal. At Houston slopes of about 1¾ to 1 at the south side plant were changed to more than 2½ to 1; those at the north side, however, were left at 1¾ to 1. At San Marcos the sedimentation tank was remodeled to give bottom slopes of 2 and 2½ to 1. At Cleveland slopes of 1 to 1 proved too flat and were changed to 6 to 1 and 9 to 1.

Such slopes necessitate tanks either very deep in proportion to their surface area or with a number of hoppers which multiply the number of points at which sludge must be removed.

Flat-bottom tanks equipped with mechanical devices to carry the sludge to a central point for removal have been tested with satisfactory results. Pearse (16) claims that more concentrated sludge is thus obtained, which is an advantage in permitting smaller units and smaller return sludge channels. There is the added advantage of greatly reducing the volume of sludge to be returned and to be disposed of.

The settling area is of utmost importance in the design of sedimentation tanks. Pratt and Gascoigne (14) give data that would indicate 1,000 gallons per square foot of settling area as a safe figure. They obtained satisfactory results with rates of 2,400 gallons. The Milwaukee tests indicated that a satisfactory result could be obtained with rates of 1,600 to 2,000 gallons. To make conservative allowance for changes in the condition and volume of sludge, 1,600 gallons of effluent per square foot was adopted to care for the maximum flow, or about 850 for average dry weather flow.

The Houston sedimentation tanks were, in 1920, handling average flows of about 1,050 and 800 gallons of effluent at the north and south side plants, respectively. The design for ultimate capacity of both plants was about 1,300. At San Marcos the average flow was equivalent to 1,000 gallons per square foot.

Until new evidence is produced rates of 800 to 1,000 appear to be the most logical to use in design.

OPERATION

Operation difficulties of activated sludge plants are gradually being ironed out. The reasons for unfavorable conditions are being found and with them the corrective measures. In the early stages of its development it was generally held that the adjustment of conditions to secure proper functioning of the plants required such skilled and technical operation as to preclude adoption of this process except at the very large cities. This subject has been discussed elsewhere, and it is only necessary to state here that this attitude is being seriously questioned on the basis of results obtained under average plant operation.

Several features of operation such as the aeration period, volume of air necessary, and the settling period have already been taken up under different devices.

In general, while for any plant there is a fairly wide range for the various factors within which operation will proceed satisfactorily, the result of exceeding these limits is disastrous.

It is known that if aeration is not adequate the resulting sludge will be light and voluminous, failing to concentrate properly in the sedimentation tank, and necessitating the return of extravagantly large volumes to the aeration tank for mixture with the incoming sewage, and correspondingly large volumes to be disposed of. Eddy (22) calls attention to the fact that assuming a plant to operate with 20 per cent returned sludge containing 2 per cent solids, a change in the sludge to 0.5 per cent solids would necessitate the return of four and one-half times as much sludge to maintain the same relation of solids.

Low temperature conditions may result in a similar condition of the sludge, and it has generally been found necessary to use more air in the winter than in the summer.

On the other hand overaeration causes a return of the colloids removed from the sewage and contained in the sludge to the sewage, with a resulting poor effluent.

The character of the sludge is also largely dependent upon the sedimentation period. If this is too short the sludge can not concentrate, but if too long, say over six hours, septic action, which ruins the sludge, is likely to start.

At the present time plant operators can best judge the condition of their sludge by its visible appearance and properties. Good sludge is, for normal sewage, golden brown in color and settles very rapidly.

The amount of sludge returned to the aerating tank depends on the concentration to be maintained. This concentration is expressed as the per cent by volume of sludge to total volume of the mixture of sewage and sludge in the aerating tank. This factor appears to admit of great variations without materially affecting the effluent. From 15 to 30 per cent or more has been used, with an average around 20 to 25 per cent.

RESULTS OBTAINED

With but few exceptions the effluents from activated sludge plants have been very good. In Table No. 55 the results obtained from the four plants surveyed are given together with reported results from other places. The analyses selected for this table are those which indicate the extent of clarification and the extent of oxidation. Because of the different determinations used at different places to measure these results it is, unfortunately, impossible to put all plants on a comparable basis.

TABLE No. 55.—*Analytical results obtained at nine activated sludge plants*

[Results in parts per million except as noted]

City	Total aeration hours	Settling minutes	Suspended matter			Settleable solids, 2 hours c. c. per liter[1]		Oxygen consumed 30′ in boiling water		
			Influent	Effluent	Per cent removal	Influent	Effluent	Influent	Effluent	Per cent removal
Houston (north side) (7)	6.7	60	200	17	92	2.5	Tr.	45	10	78
Houston (south side) (7)	8.1	70	226	7	97	2.0	Tr.	38	6.4	83
San Marcos (7)	3.5		42	3	93	Tr.	Tr.	18	8.5	53
Sherman (7)			264	73	72	5.0	3.4	64	32.0	50
Mount Vernon, N.Y. (26)	8-10		245	20—	92			[2] 154	31.0	80
Milwaukee (24)			318	11	97			132	27.0	80
Cleveland, Ohio (14)	5.8	50	231	30	87			59	15.0	75
Urbana, Ill. (13)								55	20.0	64
Worcester, England (25)	8	150	104	Tr.				[3] 76	[3] 21.0	72

City	Oxygen demand 5-day, 20° C.			Dissolved oxygen		Nitrogen as—			
						Ammonia			Nitrates in effluent
	Influent	Effluent	Per cent removal	Influent	Effluent	Influent	Effluent	Per cent removal	
Houston, (north side) (7)	115	11.0	91	0.2	5.2	17	4.3	75	4.6
Houston, (south side) (7)	112	7.4	94	.8	7.4	18	1.7	91	3.0
San Marcos (7)	57	16.0	72	2.8	7.6	17	2.8	84	5.5
Sherman (7)	165	33.0	80	2.5	6.2	26	23.0	12	1.2
Mount Vernon, N. Y. (26)									1.0
Milwaukee (24)						15	13.0	13	.9
Cleveland, Ohio (14)						11	8.4	24	
Urbana, Ill. (13)						24	0	100	12.0
Worcester, England (25)		6.3				20	26.0	−30	

[1] Tr. indicates less than 0.1 c. c.
[2] Method not stated.
[3] Computed from 4-hour determination.

With the exception of the Sherman plant, the suspended solids in the effluents are all low. At Sherman the sludge or "floc" was being carried over from the final sedimentation tank. It was very light and voluminous, as can be seen from the settleable solids results where 73 parts of suspended matter occupied 3.4 c. c. in the settling glasses. The sludge in the tanks at the time the analyses were made was comparatively new, most of the old sludge having been withdrawn shortly before. It appeared to be underaerated.

The oxygen demand results on the plants surveyed are with the exception of Sherman less than the available oxygen present in the form of dissolved oxygen and nitrates.

The use of the ammonia nitrogen determination as an indicator of the completeness or efficiency of aeration is discussed under analytical methods (p. 27.) Applying it to the results in the above table, the statement made above regarding Sherman is confirmed. With Milwaukee and Cleveland the ammoniacal nitrogen determination would indicate aeration to the point of clarification, but with relatively little oxidation. The nitrates at Milwaukee indicate this same condition. At Cleveland no nitrate determinations are given.

The Urbana results are those obtained from small fill and draw units in tests made primarily to determine the efficiency of various types of air diffusers. They are interesting particularly as they show a complete removal of ammonia nitrogen with the production of an almost equivalent amount of nitrates.

It is believed that the Sherman results are representative of the poorer effluents which may be temporarily obtained from activated sludge plants in small places where the operation is in the hands of an untrained man. Under similar circumstances and with a similar raw sewage, it is doubtful whether any other type of plant could produce a consistently better effluent.

SLUDGE (ACTIVATED)

The capacity of the activated sludge process to produce with reasonable expense a clear liquid effluent of almost any desired degree of stability is no longer questioned, except where the sewage contains disinfecting industrial wastes. Unfortunately it is not possible to stop at that point. In the process, large volumes of sludge are produced as a by-product. An economically practical treatment of this sludge to the point of disposal has not yet been assured.

Because it is so dilute and of a character to resist the removal of water by known methods it presents the big unsolved problem of the process. However, its relatively high nitrogen content, as compared with sludges from other processes, has directed investigation largely toward the recovery of this nitrogen for fertilizer purposes. Several methods of dewatering the sludge have been investigated, but the cost has always been nearly equal to the theoretical value of the nitrogen recovered. So far no plant has produced a sufficient quantity of dried sludge to demonstrate that it can be marketed on a large scale.

Volume.—The volume of sludge it is necessary to dispose of is largely dependent on the design and operation of the plant, with temperature conditions also a factor. Assuming that with proper sedimentation and adequate aeration 15,000 gallons of 98 per cent sludge have to be disposed of, a change in the concentration of the sludge to 99.5 per cent water, due to underaeration, inadequate settling capacity or cold weather, would increase the volume to about 68,000 gallons.

The following table contains the opinions of various investigators of the amount and concentration of sludge they feel must be taken care of in disposal operations. Some of the figures are the quantitative results of actual measured test, while others are general conclusions or design figures.

TABLE No. 56.—*Sludge to be disposed of in the activated sludge process*

City	Authority	Date	Gallons of sludge to be wasted per million gallons sewage	Per cent water in sludge	Pounds dry solids per million gallons
Milwaukee (18)	Hatton and Copeland	1920	12,100	97.5	1,800
Cleveland (14)	Pratt and Gascoigne	1916	6,200	97.5–98.0	1,300
Worcester, Mass. (10)	Gault	1919	13,200	98	
Nominal average (22)	Eddy	1920	10,000	98	
Manchester, England (27)	Ardern	1921	23,200–35,300	99.4–99.6	
Chicago Stock Yards (16)	Pearse	1921	41,000–47,000	99.2+	1,900–2,400

At the time of the survey, sludge at both of the Houston plants had been lagooned, and it was impossible to arrive at more than a crude estimate of the actual production. As removed from the reaeration tank it had a moisture content of 99 to 99¼ per cent.

The volume as given in the above table for Cleveland was arrived at by computation from suspended matter removed, allowing 35 per cent for liquefaction. This percentage was based on observations and analyses.

From the available data it appears that under favorable conditions from 10,000 to 30,000 gallons of 97.5 to 99 per cent sludge per million gallons will have to be disposed of. There is, however, relatively little data upon which to base any definite conclusions.

Treatment.—Many different methods have been tested to secure a satisfactory method for disposal of sludge.

Drying on beds has been practically abandoned for large cities, both because of the large area required and because by this method the full value of the sludge as a fertilizer is not obtained. Pratt and Gascoigne at Cleveland (14) concluded that "unless the unit quantities of sludge produced are materially lessened, the use of sand beds for dewatering activated sludge is financially prohibitive." Gault (10) at Worcester, Mass., stated that for local conditions "air drying of activated sludge as a means of disposal on a large scale has been demonstrated to be impracticable; air drying during the winter season is impossible." These statements are expressive of general opinion of the applicability of this method of drying to large installations. For smaller installations where the total volume of sludge produced can not warrant recovery processes and where land is readily available this method is applicable.

Lagooning is another method possible at smaller and medium size plants. At both the plants at Houston all sludge had been lagooned, up to the time of the survey, except a small amount used for tests. At the north side plant the sludge from 8–10 m. g. d. of sewage is to be treated in a pressing and drying plant which is already installed. It is expected that lagooning will be continued at the south side plant, which is now treating about 1½ m. g. d. At this plant a lagoon 300 by 100 by 10 feet was used for two years and is only half filled.

To make large installations of the activated sludge process economically feasible it is pretty well agreed that the nitrogen of the sludge must be recovered, and that the value of the sludge must be at least equal to the cost of the recovery process.

The processes now receiving most favorable attention are: (1) Concentration by sedimentation; (2) pressing; (3) centrifuging; (4) acidification in connection with pressing and centrifuging; and (5) drying by mechanical driers.

If the sludge is removed from the sedimentation tanks or reaeration tanks of the sewage-treatment plant containing more than 99 per cent water, it can, if the sludge is good, be resettled to a water content of 97.5 or 98 per cent. The reduction from 99 to 98 per cent for instance reduces the volume to be handled to half the original volume. Where sludge can be taken from the sewage treatment tanks with a water content of 98 per cent it is doubtful whether resettling is advisable. The settling period should not exceed six hours or the sludge is likely to become septic and in this condition is much more difficult to handle.

The 98 per cent sludge then passes to the presses or centrifugal machines. Under favorable conditions the water content is here reduced to about 80 to 85 per cent. The Simplex presses installed at Houston are guaranteed by the manufacturer to produce a specified amount of 80 per cent cake daily.

As preliminary to pressing or centrifuging, acid (about 0.12 per cent of the volume of the sludge, if sulphuric acid is used) is sometimes added to the sludge to counteract to a certain extent its natural slimy characteristics, and thus put it into better condition for treatment.

From the presses or centrifugal machine the 80 (plus or minus) per cent sludge is taken to heat driers. Both the direct and indirect heat types have been tested and found to be satisfactory. These produce a sludge with 10 per cent moisture, which is screened, the larger pieces being ground and sold as a low-grade fertilizer or as a filler for a higher grade fertilizer.

The actual tests made with presses, centrifugal machines, and driers have been very extensive, and while results have demonstrated possibilities and given promise of ultimate success, there has not as yet been developed apparatus which is generally acceptable to engineers.

At Milwaukee tests are still in progress, and the design for the Des Plaines River plant (9) includes both a press and a centrifugal machine. At neither place have the exact make or type of apparatus been definitely settled. The expectations are that sludge of about 98 per cent water acidulated with sulphuric acid, using 2 to 4.5 c.c. per gallon of sludge, can be successfully and economically pressed to a cake containing about 80 (75 to 85) per cent water. The Simplex presses installed at the north side plant at Houston are accepted subject to the maker's guaranty that the two 120-plate presses will, with 98 per cent sludge, produce 54,000 pounds daily of 80 per cent cake. It is planned to add 0.65 gallon of 66 Baumé sulphuric acid per 1,000 gallons of sludge. As the Simplex press was tested at Milwaukee, this guaranty is doubtless based on results obtained there. With this press a cake averaging ¾ to 1¼ inches thick and containing 80 per cent moisture was produced from 97.5 per cent sludge in 4.5 hours at a rate of 3 pounds of cake per square foot of filter cloth.

The Berrigan press made by the Worthington Corporation produced from the same sludge at Milwaukee (18) 2.89 pounds of 81.5 per cent cake per square foot of filter cake in 4.85 hours.

At the stockyards at Chicago (16) the Simplex press, the same machine used at Milwaukee, produced from 98.6 per cent sludge with 2½ hours net pressing time a 77.9 per cent cake at a rate of 4.5 pounds per square foot of filter. A 1-inch cake was considered the most practical.

Here also tests were made with acidulated sludge, using 1.5 to 2.0 c. c. of 60 Baumè sulphuric acid per gallon of sludge. With this treatment the results were much better. Parallel tests with plain and acidulated sludge gave comparative results given in the following table:

Table No. 57.—*Sludge pressing at the Chicago stockyards with and without acid* (16)

	Net pressing time (hours)	Per cent water at start	Per cent water of cake	Pounds of cake	Pounds cake per square foot filter	Pounds dry solids
Without acid	3.5	98.66	82.5	114	6.0	20.0
With acid [1]	3.5	98.57	75.7	114	6.0	27.7
Without acid	4.0	98.91	82.1	111	5.8	19.9
With acid [1]	2.15	98.83	78.6	109	5.7	23.3

[1] 2 c. c. 60 Baumé sulphuric acid per gallon sludge.

Allowing for the full cycle of filling, pressing, dumping, and cleaning, it was concluded that the yield with acidified sludge is from 40 to 100 per cent greater, in terms of dry solids, than the unacidified sludge. In general the report of the stockyard tests (16) gives the following as advantages and disadvantages of acidification:

Advantages:

1. The yield and capacity of press are increased.
2. The nitrogen and fat content of the sludge are increased.
3. The filter cloths do not clog as rapidly.
4. The sludge cake does not become septic.

Disadvantages:

1. The cost of the acid.
2. The addition of another step in the process, as well as the requirement of more equipment.

Eddy (22), assuming 15,000 gallons of 98 per cent sludge per million gallons of sewage with 6 per cent ammonia on dry basis, and estimating sulphuric acid at 1 cent per pound and ammonia at $4 per unit, gives a theoretical increase in value of the sludge due to acidification of $3.62 per million gallons with an acid cost of $2.70. This makes no allowance for losses but gives no credit to the operating value of conditioning the sludge for more economical pressing.

Data on experiments with centrifugal machines are very meager. The Shafer-ter-Meer and Besco-ter-Meer machines have both been subjected to more or less investigation, especially at Milwaukee. With the latter cakes of 80 to 85 per cent moistures have been obtained but the effluent contains much suspended matter which has been extremely difficult to remove. The authors are not aware of any permanent operating plant using centrifugal machines for sludge treatment.

In order to market the sludge the moisture must be reduced to 10 per cent. This can be accomplished only by drying with heat. Standard makes of driers, both direct and indirect heat types, have been tested, and it is well demonstrated that no unusual difficulties are encountered.

The Milwaukee tests (18) have been conducted with a Buckeye direct-indirect drier 16 feet long and 23 inches in diameter. With this, 82 per cent sludge has been dried to bone dryness with no loss of nitrogen.

The installation at Houston, Tex., has one Buckeye direct-indirect drier, 40 feet long and 60 inches in diameter, to handle sludge from a 10 m. g. d. activated sludge plant. The makers' guarantee the evaporation of 10 pounds of water per pound of 13,500 B. t. u. fuel.

Hatton at Milwaukee (18) reports that "two reputable manufacturers of driers have submitted to us full plans and propositions for driers in which they guarantee to reduce the moisture from the sludge at the rate of 10 pounds of water evaporated per pound of combustible."

COSTS

Cost data of the activated sludge process including the disposal of the sludge can hardly be considered to be beyond the estimating stage. Costs based upon experimental results, even if the tests be of fairly large magnitude, may differ greatly from those obtained in actual practice. Labor, depreciation of the installation, repairs, and general maintenance costs must be secured for a period of years under normal operating conditions. It is not believed that possession of such data can be claimed at any place.

Cost data are, moreover, most valuable when available for comparison, e. g., to compare the installation cost and operating costs of the activated sludge with other processes, such as Imhoff tanks and trickling filters. Most of the installation costs of activated sludge plants were incurred during the period of high war prices and are, therefore, directly comparable only with other plants constructed during the same period. Accurate comparative operating costs are also difficult to secure, as interest on investment and depreciation are seldom included in issued statements.

Installation costs.—With the exception of the two plants at Houston there are no actual construction cost data obtainable for installations in this country of plants with a million gallons daily capacity. Dalhyn (5) reports one in Canada, Woodstock. The costs of a number of installations have been estimated and actual costs are available for some of the smaller plants. The table following contains cost data available from some plants in this country together with a few foreign and Canadian plants:

TABLE No. 58.—*Installation costs of some activated-sludge plants*

Plant	Date	Capacity m. g. d.	Cost per m. g. d. capacity	Sludge-drying plant included	Remarks
Houston (north side) (7)	1919	[1] 10.0	[3] 25,500	No.	Sludge-drying plant; cost $85,000.
Houston (south side) (7)	1919	[1] 5.0	[3] 25,000	No.	
San Marcos (7)	1916	[2] .2	[3] 25,000	No.	Septic tank, estimated at $1,500; could treat greater flow.
Sherman (7)	1919	[1] 1.5	[3] [4] 26,700	No.	Plant only partly completed; estimate balance to complete, $5,000.
Milwaukee (28)	1920	[1] 85.0	[4] 59,000	Yes.	Include recovery of 17 acres of land from lake, pile foundations for all structures and provisions for extensions.
Chicago (29)	1917	[1] 50.0	[4] 65,000	Yes.	For stock-yard wastes.
Fitchburg (30)	1916	[1] 5.5	[4] 57,000	(?)	
Bloomington, Ill. (31)	1920	[1] 5.0	[4] 108,000	(?)	Designed for 50,000 population.
Woodstock, Ontario, Canada (32)	1920	[2] 1.8	[3] 32,200	No.	
Worcester, England (33)	1919	[1] 1.8	[4] 15,000	(?)	
Escanaba, Mich. (34)	1917	[1] 1.5	27,000	Yes.	Contract costs.
Los Angeles, Calif. (35)	1921	....	[4] 60,000	(?)	Estimate by Fuller, Whipple, Mulholland.

[1] Rated. [2] Present operating. [3] Actual. [4] Estimated.

Local conditions and date of construction are items of the greatest importance. At Milwaukee where land must be made and pile foundations are necessary for all structures, the cost is naturally increased. The cost of plants built or estimated while high war prices prevailed are not comparable with costs during normal times. Moreover, costs or estimates at some places include items such as long outfall or intercepting sewers which do not affect the installation costs of the treatment plant proper.

The cost figures in the above table may be roughly divided into four groups. First the foreign plant at Worcester, England, estimated at $15,000 per million gallons; second, six plants averaging $26,900 per million gallons, in every one of which the costs are practically actual construction costs; third, four plants averaging $60,000 per million gallons all of which are estimates; and fourth, the plant at Bloomington, Ill., estimated at $108,000 per million gallons. It has not been possible to secure figures in sufficient detail to account for the differences between these groups. Local conditions may necessitate much more expensive work at one place than at another, and the fluctuations of material and labor prices during the past few years have covered such a wide range that unit costs are essential for satisfactory comparisons.

In comparison with plants including Imhoff tanks, trickling filters, and secondary sedimentation tanks, the activated sludge plant requires a lower initial investment in construction. Eddy (30) in 1916 prepared comparative estimates for a 5.5 m. g. d. plant at Fitchburg, Mass., the Imhoff filter plant being $431,000 and the activated sludge $314,000. The Imhoff filter plant when actually built in 1914–15 cost $350,800.

Pearse (31) gives comparative estimates for a plant at Bloomington, Ill., as $650,000 and $540,000 for the Imhoff filter plant and activated sludge processes, respectively. The plant was to serve a future population of 50,000.

Goddard and Ehlers (36) estimated that in general the initial costs of activated sludge plant are approximately half of a screen-sedimentation filtration disinfection plant.

Operating costs.—Operating costs including maintenance and depreciation are very meager and for the most part estimates based upon experimental data. Many of the estiments should, however, work out in practice as they are based upon experiments conducted on a scale almost comparable with actual operating conditions.

In plants where the sludge is not dried for fertilizer the gross cost and net cost of operation are the same. Where, however, sludge recovery is practiced the net cost becomes the gross cost less the profit on the sludge. In such plants the net cost is the cost of treating the sewage including interest, maintenance, and depreciation of the treatment plant, plus the cost of drying and marketing the sludge, also including the usual items of interest, etc., less the market value of the sludge.

These figures, except in a very few cases, are not available, but it appears that with a plant operating near capacity and recovering the sludge the net operating cost will be from $15 to $20 per million gallons.

At Houston the operating costs, exclusive of interest and depreciation were, for the year 1919, $14.70 and $21.20 for the north and south side plants, respectively. At both plants the sludge was lagooned. The details of the items entering these totals are given on page 85. Neither of the Houston plants were operating at full capacity, but their total expenses for supervision were about the same as if they had been. If the data given in this table be used with the operating capacities of the plants, and if these capacities be taken as 8 and 4 m. g. d. for the north and south side plants, respectively (they were designed for 10 and 5 m. g. d.), the operating costs can be computed to $13.48 and $13.50 per m. g. d. The power costs and supplies in this computation are assumed to remain the same, but the cost for chief operator, operators, laborer, and chemist are assumed to be the same per m. g. d. treated in total, regardless of the volume treated. Estimating interest and depreciation at 10 per cent of the construction cost these gross figures would become $22.30 and $21.50. If at the north side plant the recovered sludge yields a net profit of $3.50 per million gallons the net cost becomes about $19.

At Milwaukee Hatton (28) estimated a net cost of $15.58. The operating cost, including sludge drying, is estimated at $33.58, of which $14.07 is capital charge and $19.51 operating costs. The sludge is estimated to be worth $18 per m. g. on a basis of 1 ton of 4.5 per cent nitrogen, 10 per cent moisture, sludge per million gallons with nitrogen at $4 per unit. This estimate was later revised (31) to give a net cost of $17 per million gallons, with treatment and sludge drying costing a total of $35, from which the value of the sludge, $18, is deducted.

The San Marcos plant was operating in 1919 at a cost of about $14.50 per m. g., exclusive of interest and depreciation. Allowing 10 per cent of the plant cost as annual charge for these items, the total operating cost would be about $21. At this plant sludge can not be considered either an asset or liability. It is not recovered but costs very little to dispose of, because of available ground adjacent to the plant on which it can be applied.

No fair estimate of the costs of the Sherman plant is possible. Only half the plant is in use; but the construction costs can not be divided, as the unused half has never been completely finished. The half in use is not operating at capacity, and there is little control over the amount of air used.

The plant as operating is costing for operation alone, exclusive of interest and depreciation, about $28 per million gallons treated. One operator at $100 per month is charged entirely to the sewage plant, although he gives probably half of his time to a small incinerator in which the city's garbage is burned. Power is estimated at $2,000 per annum on the basis of a 22-horsepower motor under full load with current at 1½ cents per kilowatt hour. A 10-horsepower motor would probably be ample with the present flow.

It is probable that with the plant operating at capacity the costs would not be far from those figures already given for the other plants, probably about $20 per million gallons.

LITERATURE REFERRED TO IN DISCUSSION OF ACTIVATED SLUDGE

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FINE SCREENING

"There is no agreement among engineers as to the size of the opening which is on the boundary between coarse and fine screening. In a general way the tendency of the present time seems to be to regard an opening of one-fourth inch as the maximum limit for fine screenings."[a] Screens of this type were found only at Baltimore, Md., the Irondequoit plant at Rochester, N. Y., and San Marcos, Tex. All of these screens have been described in detail under these plants, and reference is made to these descriptions.

The function of fine screens is confined to the removal of solids. They have been used for this purpose in three ways: First, as a complete treatment for the removal of the larger and especially the floating solids at places where there are adequate dilution facilities to dispose of sewage by this method, the screens serving to prevent surface nuisances. Second, as preliminary to tank treatment for the removal of the large and nonsettleable solids. This is the situation at the Irondequoit plant at Rochester, and it is for this purpose that screens are recommended as preliminary to treatment in the aeration tanks of the activated sludge process. Third, as a protection for nozzles on trickling filters to remove solids carried over from sedimentation tanks which are capable of clogging the nozzles. The screens are used for this purpose at Baltimore, Md., and have effected a reduction of about 87 per cent in the number of nozzles cleaned.

At only one plant, the Irondequoit plant at Rochester, were analytical determinations made of the influent and effluent of the screens. These results are given in detail under the discussion of this plant. The following table gives the averages of the suspended matter results for the various size screens and, for comparison, the results obtained with fine screens of the same and other types at one or two other places.

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[a] American Sewerage Practice, Metcalf and Eddy. Vol. III, p. 310.

TABLE No. 59.—*Main structural features and results obtained with some fine screens*

Plant	Type of screen	Size of opening	Suspended matter, p. p. m.			Per cent removal based on screenings removed
			Influent	Effluent	Per cent removal	
Rochester, N. Y. (Irondequoit).[1]	Riensch-Wurl	$\frac{1}{16}$ by 2 inches	203	199	+2	2±
Do	do	⅛ by 2 inches	211	222	−5	
Do	do	⅛ by 2 inches	130	156	−20	
North Plainfield,[2] Plainfield, and Dunellen, N. J.	do	$\frac{1}{16}$ by 2 inches	[3] 143	[3] 161	−12	[4] 8±
Cleveland, Ohio[5]	Drum	50-mesh	346	270	22	28
Do.[5]	do	80-mesh	342	272	20	23
Do.[5]	do	120-mesh	312	256	18	24
Brockton, Mass.[6]	do	36-mesh	983	282	71	----------

[1] Survey results

[2] Operating Data of Fine Screens and Imhoff Tanks. John R. Downes, Public Works, vol. 50, pp. 370–371.

[3] Influent is average of 3 years 1917–1919, inclusive, during which time a yearly average varied from 140–148. Effluent is average for year 1920.

[4] Estimated.

[5] Report on Tests at Sewage Testing Station, Clevelend, Ohio. Robert Hoffman, R. Winthrop Pratt, Harry B. Hommon, 1914, p. 60.

[6] The Clarification of Sewage by Fine Screens, Kenneth Allen, Proceedings Am. Soc. C. E., Vol. XL, No. 6, pp. 1839–1909.

Of the four results from Riensch-Wurl screens, only one showed any removal based upon the suspended matter results of the raw and screened sewage, the other three results giving higher suspended matter in the screened than in the raw sample.

The reason for this condition has been discussed under the suspended matter determination, where it was shown that the suspended matter results for the raw sewage at Rochester were not accurate closer than 9 per cent. The difficulty of securing representative samples of sewage containing large pieces of suspended solids prevents accuracy within the limits of efficiency, unless the efficiencies are greater than 10 to 15 per cent.

As based upon the screenings removed the average efficiency of the Riensch-Wurl screens at Rochester was 2 per cent and of that at Plainfield 8 per cent.

The drum screens covered with a fine mesh wire cloth give higher removals amounting to 20 to 30 per cent at the Cleveland testing station, and 71 per cent at Brockton, Mass. In this latter case the high removal is due largely to the extreme concentration of the raw sewage, the effluent from the screens here containing more suspended solids than any of the others listed in the above table.

The rates attainable on the Riensch-Wurl screens at Rochester, which have a diameter of 12 feet, have been determined by N. A. Brown, special assistant engineer, to be from 16 to 40 m. g. d. with a loss of head of 0.4 to 1 foot, respectively, for the one eighth-inch slot, and from 16 to 35 m. g. d. with a loss of head of 1.2 to 1.7 feet, respectively, for the one-sixteenth-inch slot.

The use of fine screens in this country has been largely restricted to the removal of the larger solids likely to produce visible surface pollution when sewage is disposed of by dilution. The results at Rochester would indicate that they are not of any great value as preliminary treatment before sedimentation in tanks. As an intermediate treatment between tank and trickling filters, Baltimore has found the screens useful, but when installed at Atlanta for this purpose they were found to be unnecessary and their use was discontinued. Relative to the screens at Brockton, which preceded Imhoff tanks, Downes[9] states:

> It is interesting to note that, outside of interest charges, the comparative costs as between screening and removing the objectionable solids from the tanks by hand are just about equal; that is to say, the time now spent by a watchman on the screen and the cost of power about equal the cost of labor in removing the coarse solids. The plant, however, is much more workable and the nature of the labor much less objectionable when the solids are removed before reaching the tanks.

As discussed under activated sludge the use of fine screens as a preliminary device ahead of the aeration tanks has been recommended, and as this process develops the fine screens may be accepted as essential.

The general attitude toward fine screens among the engineers of this country has not become crystallized. Allen[10] stated in 1914:

> The use of fine screens for sewage deserves more serious consideration than it has received heretofore in America. * * * it is the writer's opinion that fine screening will be adopted in the future by many towns situated on bodies of water which are capable of assimilating the effluent; possibly, also, as a preliminary process to tank treatment, filtration, and disinfection. On the other hand, the relatively high cost of attendance and the probable lack of market for screenings, when compared with conditions abroad, will probably serve to prevent the marked increase in their use in the United States which has been experienced in Germany.

Fuller, in his "Sewage Disposal," published in 1912, states: "Screens have a far greater field for usefulness than is generally recognized in America." But in his report to the Metropolitan Sewerage Commission of New York, in 1913, he stated that he preferred fine screens to sedimentation tanks only where it was advisable or necessary to remove only relatively large sewage matters in suspension.

Metcalf and Eddy[11] on the other hand are less optimistic, saying:

> It seems probable that the day of elaborate fine screening has passed, in view of the results attained with improved sedimentation tanks. If the matter removed by fine screening can be successfully taken out in sedimentation basins, the cost will usually be less.

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[9] See note [2], Table No. 59.

[10] See note [6], Table No. 59.

[11] American Sewage Practice, Metcalf and Eddy. Vol. III, p. 252.

They also refer to the opinions and experiences of Hering, Pearse, and others, which tend to discourage the use of fine screens in connection with sedimentation tanks, and to restrict the field to plants where the removal of large solids is sufficient treatment before disposal by dilution.

SLUDGE

Sludge is the principal by-product of sewage treatment. It consists of the solids, other than screenings, removed from the sewage by the treatment processes. As the removal of these solids is one of two functions of a treatment plant, the ultimate disposal of sludge is a necessary part of the operation of any plant.

Sludges from different treatment processes vary greatly in the volume produced and in physical characteristics and chemical composition.

Volume.—The amount of sludge produced per million gallons of sewage treated depends not only upon the treatment process and device employed, but upon the character of the sewage treated. While no average values can be given for the quantities produced by different processes, there are, with the same sewage, general tendencies which are typical of the processes. Thus, Imhoff tanks produce a relatively low moisture content, well digested sludge; activated sludge produces the largest volume with the highest moisture content; and chemical precipitation produces the largest amount of dry solids.

In a general comparison, Eddy [13] has used the following table:

TABLE NO. 60.—*Nomina. volume of sludge produced by different processes of sewage treatment*

Treatment process	Normal volume of sludge per million gallons of sewage treated (gallons)	Proportion of solids in sludge	Specific gravity of sludge	Weight of dry solids in sludge per million gallons of sewage treated (pounds)
Activated sludge	10,000	2.00	1.006	1,675
Chemical precipitation	5,000	7.50	1.040	3,250
Sedimentation	2,500	5.00	1.020	1,060
Septic tank	500	5.00	1.040	220
Imhoff tank	500	15.00	1.070	670
Trickling filter-humus tank	500	7.50	1.025	320

Judging by the information obtainable at the plants surveyed, records of sludge production are not as a rule kept. Of the 12 cities visited, 5 or 6 had information on this phase of operation, and 2 or 3 others kept records of the amount of sludge removed from beds, but had no determinations of moisture by which it would be possible

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[13] Lights and shadows of the activated sludge process. H. P. Eddy, Public Works, vol. 51, pp. 112-115, 130-133

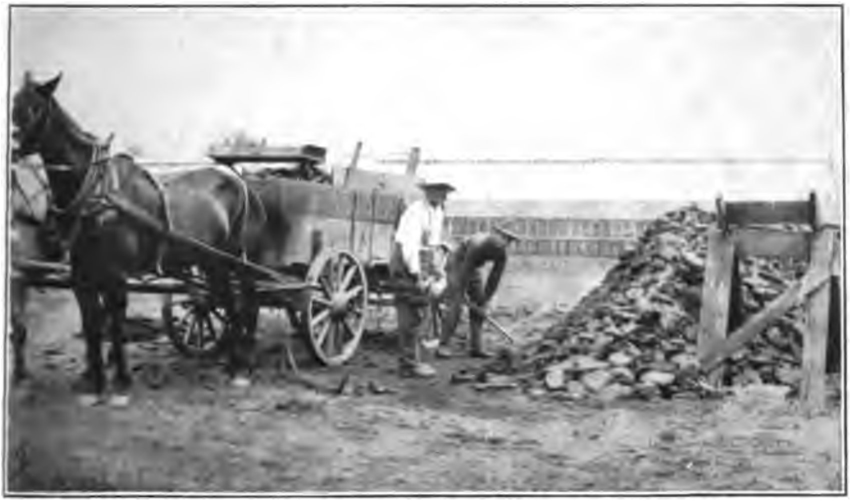

FIG. 33.—FARMERS TAKING SLUDGE AT ALLIANCE, OHIO

FIG. 34.—SPREADING SLUDGE WITH MANURE SPREADER AT CANTON, OHIO

to approximate the volume deposited in the tanks. The following table contains the local data which were obtained:

TABLE No. 61.—*Volume of sludge deposited per million gallons of sewage treated*

City	Year for which record is given	Volume of sludge deposited per million gallons (cubic yards)	Per cent water	Specific gravity
Baltimore, Md., hydrolytic tanks	....	5.95	91.6	1.02
Columbus, Ohio, Imhoff tanks	1920	3.08	....	....
Fitchburg, Mass., Imhoff tanks	1919	4.45	87.9	1.04
Fitchburg, Mass., secondary sedimentation tanks	1919	1.31	98.9	1.02
Reading, Pa., septic tank	1918	2.62	....	....
Reading, Pa., average of 4 secondary sedimentation tanks	1918	4.66	....	....
Rochester, N. Y. (Brighton), Imhoff tank	1918	1.30	83.6	....
Rochester, N. Y. (Brighton), secondary sedimentation tanks	1918	.97	87.8	....
Rochester, N. Y. (Irondequoit), Imhoff tanks	1919	1.38	79.0	....

At Alliance, Ohio, a record was kept of the sludge beds cleaned, from which an approximate volume of bed-dried sludge was obtainable; but as no moisture determinations were made, the volume of sludge as deposited in the tanks was not computable.

Canton, Ohio, stopped measuring sludge removal in 1918 when it became necessary to supplement the sludge beds by lagoons and broadcast application to fields.

The records at Atlanta had suffered by the absence of the regular plant operator, who entered the Army in the fall of 1917 and returned to the plant only a week before this survey was made.

At Houston, Tex., and Lexington, Ky., only approximate estimates were possible. These were not included in the above table, as it was not felt that they are sufficiently accurate. No records of any sort were kept at San Marcos or Sherman.

Analyses of sludge.—With the exception of San Marcos, Tex., samples of sludge were taken at all the plants surveyed, and analyzed. The moisture and specific gravity determinations were, of course, made at the plants, and the dried samples were then shipped to the office at Cincinnati, Ohio, and the other determination made after the entire survey was completed.

The value of the fertilizing ingredients, especially the nitrogen, is at present one of the important subjects in sewage treatment because of the development of the activated sludge process whereby sludge is produced sufficiently high in nitrogen to bring its recovery within the limits of economic possibilities.

For this reason it was considered advisable to include with the analyses made on the survey those of sludges at other cities. These are contained in the following table, which is arranged to group sludges from different devices or processes together.

TABLE No. 62.—*Sludge analyses*

City.	References	Specific gravity	Per cent water	Per cent volatile matter	Per cent dry basis: Total nitrogen	Phosphates as P_2O_5	Potassium as K_2O	Ether soluble matter
From septic tanks:								
Worcester, Mass	(1)	-------	-------	43.9	3.01	-------	-------	-------
Columbus, Ohio[1]	(1)	1.081	83.4	26.8	1.34	-------	-------	6.8
Cleveland, Ohio	(2)	1.088	89.2	40.8	1.50	1.2	-------	9.0
Reading, Pa	(1)	-------	91.8	47.0	-------	-------	-------	-------
Philadelphia, Pa.[2]	(1)	1.048	86.9	49.0	1.35	-------	-------	7.3
Waterbury, Conn.[3]	(1)	1.025	85.8	45.5	1.35	-------	-------	10.8
Akron, Ohio	(15)	1.07	84.0	43.8	.96	-------	-------	6.5
Baltimore, Md.[3]	(9)	-------	79.2	73.8	2.64	-------	-------	9.0
From Imhoff tanks:								
Worcester, Mass	(1)	-------	-------	40.1	2.63	-------	-------	-------
Philadelphia, Pa	(1)	1.085	82.5	38.0	1.2	-------	-------	6.5
Cleveland, Ohio	(2)	1.057	85.3	34.0	1.2	-------	-------	8.3
Columbus, Ohio	(14)	.997	96.2	-------	2.8	1.6	.6	24.4
Alliance, Ohio	(14)	1.012	78.4	52.1	2.5	1.9	.4	8.5
Atlanta, Ga. (Peachtree)	(14)	1.016	92.2	47.3	2.3	1.6	.5	12.2
Atlanta, Ga. (Intrenchment)[4]	(3)	1.02	87.0	30.1	1.25	-------	-------	6.1
Baltimore, Md	(14)	.992	94.2	67.7	3.6	.8	.2	20.6
Do	(9)	1.017	92.3	62.7	.75	.58	.19	-------
Fitchburg, Mass	(14)	1.034	83.7	70.4	2.0	1.6	.6	7.7
Lexington, Ky	(14)	1.014	92.0	51.7	3.0	2.0	.8	9.2
Canton, Ohio	(14)	.990	86.5	37.8	1.6	1.2	.2	12.9
Rochester, N. Y. (Brighton)	(14)	1.015	86.5	32.3	1.9	.8	.2	6.0
Rochester, N. Y. (Irondequoit)	(14)	1.031	87.4	47.6	2.2	.8	.6	8.0
Eight cities[5]	(6)	-------	-------	36.1	1.61	1.15	-------	-------
Akron, Ohio	(15)	1.11	75.0	48.4	.80	-------	-------	6.2
From activated sludge process:								
Houston, Tex	(12)(14)	-------	-------	44.7	3.0	2.1	.4	5.0
Do	(13)(14)	-------	-------	46.0	3.1	2.2	.4	5.4
Cleveland, Ohio[6]	(4)	-------	97.5+	49.0	3.21	1.73	.20	6.77
Milwaukee, Wis.[7]	(5)	-------	99.3	57.5	4.5	2.0	-------	5.4
Do.[8]	(5)	-------	10.5	52.5	5.1	1.5	-------	5.3
Sherman, Tex	(14)	-------	-------	76.6	5.8	2.8	.6	10.4
Urbana, Ill	-------	-------	-------	-------	-------	-------	-------	-------
Syracuse, N. Y	(8)	-------	-------	-------	5.1	-------	-------	17.7
Worcester, Mass.[9]	(10)	-------	-------	-------	4.06	2.26	-------	-------
Garbage tankage:								
Los Angeles, Calif	(7)	-------	-------	-------	3.05	1.96	1.22	1.71
Cleveland, Ohio	-------	-------	-------	-------	3.1	4.0	-------	-------
Horse manure	(11)	-------	-------	-------	1.7	.26	1.5	-------

[1] Average of 5 analyses.
[2] Average of 2 analyses.
[3] From hydrolytic tank.
[4] Average of 36 analyses.
[5] Average of analyses of air-dried sludge from 8 cities.
[6] Average of 18 to 20 analyses; only 3 for potassium.
[7] From sedimentation tank.
[8] Dried press cake
[9] Average of 4 analyses.

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(3) Experience and Results of Four Years' Operation of Coarse Screens, Grit Chambers, Imhoff Tanks, and Trickling Filters at Atlanta, Ga. Charles C. Hommon. Paper read at 23d Annual Convention of American Society of Municipal Improvements, October, 1913.

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(9) Nine Years' Operation of the Baltimore Sewage Works. T. C. Schaetzle. Engineering News-Record, vol. 87, p. 98.
(10) Annual Report Superintentent of Sewers, 1919.
(11) Bulletin 246, Ohio Agricultural Experiment Station.
(12) From drier.
(13) From dust room.
(14) Survey results.
(15) Report on Sewage Testing Station, Akron, Ohio, 1912. Harry B. Hommon.

It is noted that the specific gravities of three of the sludges analyzed on the survey are less than 1.0. These samples contained at the time of analysis large numbers of minute gas bubbles which could not be removed. The analyses were made on freshly drawn samples and the results were checked.

While there is more or less variation in sludges produced by the same process from different sewages, the one outstanding difference in the above table lies in the nitrogen contents of sludge from the activated sludge process as compared with other sludges, the former averaging 4.2 per cent or more and the latter 2.1 per cent.

With acid treatment the nitrogen in activated sludge has been further increased. Eddy[13] estimates this increase to average 12 per cent. He also states that, since in pressing solids low in nitrogen are lost with the press liquor, there is an apparent nitrogen increase in pressed sludge, which he estimates at 9 per cent.

After ignition for the determination of volatile matter the residual ash was analyzed. The results of these analyses are contained in the following table. For the sake of completeness the phosphates and potash already recorded in Table No. 62 are repeated here.

Table No. 63.—*Mineral analyses of the ash from sludges obtained on the survey*

City	Type of tank	Results in per cent of sludge dried at 100° C.										Per cent error
		SiO_2 and HCl insoluble residue	Al_2O_3 and Fe_2O_3	P_2O_5	SO_3	CaO	MgO	K_2O	Na_2O	Total by analysis	Ash found	
Alliance, Ohio	Imhoff	35.8	8.2	1.9	0.9	1.8	0.3	0.4	2.0	47.9	51.3	3.4+
Atlanta, Ga.	do	26.8	18.5	1.6	1.4	3.6	.8	.5	1.7	52.7	54.9	2.2+
Baltimore, Md.	do	22.6	6.4	.8	1.0	2.4	.3	.2	1.9	32.3	35.6	3.3+
Do	Digestion	17.7	3.4	1.0	2.3	1.7	.1	.5	.4	29.6	27.1	2.5−
Canton, Ohio	Imhoff	44.3	11.0	1.2	1.5	3.9	.3	.2	1.7	62.2	64.1	1.9+
Columbus, Ohio	do	22.1	4.2	1.6	2.2	4.5	.5	.6	.8	37.1	36.5	.6−
Fitchburg, Mass.	do	47.8	9.0	1.6	.6	.8	.3	.6	.5	60.8	61.2	.4+
Lexington, Ky.	do	31.1	6.1	2.0	1.0	5.0	.4	.8	.7	48.3	47.1	1.2−
Rochester, N. Y. (Brighton).	do	58.1	5.2	.8	.6	2.7	.5	.2	2.0	67.7	70.1	2.4+
Rochester, N. Y. (Irondequoit).	do	40.8	3.6	.8	1.0	2.5	.3	.6	1.2	52.4	50.8	1.6−
Average		34.7	7.6	1.3	1.2	2.9	.4	.5	1.3	49.1	49.9	.8
Houston, Tex., drier	Activated sludge	44.7	7.1	2.1	.3	1.4	.4	.4	.6	55.3	57.0	1.7+
Houston, Tex., dust	do	42.4	6.5	2.2	.3	1.3	.4	.4	.6	54.0	54.1	.1+
Sherman, Tex.	do	9.2	2.9	2.8	1.0	2.5	.2	.6	3.3	23.4	22.6	.8−

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[13] Loc. cit. p. 173.

Sludge as a fertilizer.—The use of sewage sludge as a fertilizer is receiving more attention now than ever before in this country, due to the production of a relatively high nitrogen sludge by the activated sludge process. There appear, however, to be some grounds to question the general tendency to disregard sludges from other processes.

The utilization of sludge may be viewed from two angles. First, the application of sludge direct to the soil either in liquid form as it comes from the tanks or in a solid form as it is taken from drying beds. This use is restricted to areas not far distant from the treatment plant. Second, the production of an article comparable in form to commercial fertilizers, and with sufficient chemical fertilizing ingredients to justify its use as a filler for high-grade fertilizers, or as a low-grade fertilizer by itself.

Up to the time activated sludge was developed the second method was practically precluded by the low nitrogen content as compared with the cost of the preparation. It is believed, however, that sufficient attention has not been given to the first method, especially where conditions can be favorably developed.

It is probable that this has been due to the fact that, for the most part, only the chemical fertilizing ingredients of the sludge have been taken into consideration, whereas the effect of the organic matter in the sludge on the texture of the soil and the fertility value of the humus formed from the sludge are factors well worthy of consideration.

Bach and Frank [14] conclude that the physical quality of character is equally as important as the content of nitrogen. Similar expressions have been made by Imhoff and others, but the general tendency has been to deprecate the value of sludge because of its low chemical fertilizing constituents.

These factors are well recognized in the case of barnyard or stall manure in which the plant-food content is but little, if any, higher than in many sludges. "In general, stall manures are found to have a higher manurial value than is indicated by the amount of phosphorus, potash, and nitrogen which they contain. Through them there is introduced into the soil large quantities of humus bodies, whereby the physical state of the soil is profoundly modified and its adaptability to the growth of crops, as a rule, increased." [15]

Fowler in an article on activated sludge states, "Among other things peat has been shown to contain substances that stimulate plant growth termed auximones. These are produced by bacteria working on organic matter, rendering it available for plant life and assisting in the production of the better-known vitamines, which are an important ingredient of animal food. It is believed that the bacteria in activated sludge may produce auximones, and that it is for this reason that this material shows a superiority to other manures."[16]

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[14] H. Bach and L. C. Frank, Fresh Sludge and Decomposed Sludge, Eng. Record, vol. 68, p. 331.

[15] Wiley, Principles and Practice of Agricultural Analyses, Vol. II.

Bottomley[17] in 1915 gives the name auximones to those organic substances necessary in small amounts for the growth of plants and in some respects analogous to Suziki's "orizinins," or Funk's "vitamines," but differing from vitamines in that they are not destroyed by heat. They are plant-food accessories.

It is not believed that sewage sludges have ever, as yet, been tested for auximones. The possibility of their presence together with the other values inherent in sludges for plant production has not been given general attention.

Popular prejudice has also militated against the use of the sewage sludge. At one city visited a teacher of botany, while admitting the increased yield from sludge treated land, urged against its use because the "fruit" would not be "fit" to eat.

The treatment plant operator who has to dispose of his sludge after its removal from drying beds can, in many cases, develop a demand for this sludge among farmers in the vicinity of the plant. The expense of hauling sludge from the plant can be saved, and, after a time, a small charge, probably sufficient to pay for the labor of cleaning the beds, can be made for the sludge.

At three plants visited on this survey, Alliance, Ohio, Canton, Ohio, and Rochester, N. Y. (Irondequoit plant), the local farmers were making extensive use of the sludge, calling for it at the plant and, at Rochester, paying a small sum for it. At Lexington, Ky., also, farmers were experimenting with the sludge in 1920 and using it in increasing amounts in 1921. Some was used at Baltimore, Md., but the bulk of the bed-dried sludge at this plant was sold to a reduction company which maintained a drying plant on adjacent land.

At no place was any extensive information available from which quantitative results of the use of sludge could be determined. General opinions and experience were, however, very favorable.

At Alliance, Ohio, four farmers were interviewed. No. 1 with a clay loam soil used undigested sludge from plain sedimentation tanks for grass, corn, and wheat. He considered sludge with 75 per cent moisture as taken from the beds to be worth twice its weight of barnyard manure. When used as a top dressing, followed by lime which he uses also with manures, on wheat and clover, he had the biggest crops he had ever raised. With too heavy application the crop never heads, and only a rank growth is produced. He felt he was still getting benefit from sludge applied four years previously. However, he has not hauled any sludge the past few years as he has not had time.

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[16] Digest, by Kenneth Allen, of monograph by Dr. Gilbert J. Fowler, Engineering and Contracting, Aug. 25, 1921.

[17] A Bacterial Test for Plant Food Accessories (Auximones). W. B. Bottomley. Proc. Roy. Soc. London, vol. 89, p. 102.

No. 2 hauled bed dried digested sludge 4 miles and used it for corn, wheat, grass, and potatoes on a poor clay land known as "Lexington clay." He claimed an increased yield of about 100 per cent for the corn, wheat, and grass over similar land receiving no fertilizer. The potato crop failed because of a dry season. One field treated with sludge eight years previously is, in his opinion, still showing the benefit. In general he considers sludge to be of about the same value as barnyard manure, but harder to handle.

No. 3 has been using sludge since 1916 for wheat and corn, hauling it 2½ miles. He has used sludge only with barnyard manure followed with lime. He could give no specific results, but considered sludge slightly superior to manure, the greatest objection being the odor if the sludge is piled.

No. 4 has hauled sludge 1½ miles and used it for corn, oats, wheat, and grass (timothy). He does not think he was benefited very much in the corn yield; the oats and wheat were good, but a phosphate fertilizer was used with the sludge; the grass, however, was the best he had ever had. He uses about 10 loads per acre, the same as when using barnyard manure, spreading by hand as a top dressing, but feels that it would be better to plow it under. Given his choice he would prefer barnyard manure as giving more lasting benefit, but he considers the sludge well worth hauling.

At Baltimore the hydrolytic tank sludge from the beds went to a drying plant. Several farmers used the screenings from the coarse bar screens, but the only sludge available to them was that from the beds located by the Imhoff tanks, of which only one or two units were in operation during 1919 and 1920. The farmers remove the sludge from the beds, saving this expense, and pay in addition 25 cents per load, which may be one or two tons according to the size of the wagon or truck.

One farmer, No. 5, considered sludge "too strong," claiming that it "burned up the crops." This is fairly common experience where too much sludge is used or where the soil is particularly dry during a growing season. This farmer has had good results with beans when using sludge direct from the tanks, applying about 4,000 gallons per acre.

No. 6, the superintendent of the sludge drying plant, reported a yield of 17 bushels of potatoes from 1 bushel of seed when using heat-dried sludge. He tested eggplants, sludging 5 plants and using 5 plants as a check without any fertilizer. The 5 sludged vines yielded 40 matured eggplants, but the 5 check vines only 1 or 2 poor plants. With cucumbers, which are considered hard to raise in that section, he obtained, with sludge fertilization, yields five times as large as without fertilization. It is unfortunate that no data were kept of the amount of sludge used or that no other fertilizer was used to compare with the sludge.

No. 7, using bed-dried sludge on grass, considered it the equal of barnyard manure, reporting an increased yield due to sludge of at least two to two and one-half times that of unfertilized fields.

The farmers at Canton, Ohio, were the most enthusiastic users of sludge met during the survey. Six, including the superintendent of the sewage-treatment plant, were interviewed. No. 8, the superintendent of the plant, has used sludge on the farm connected with the plant. The soil is sandy and was badly run down when taken over by the city. In 1918 sludge was applied, 6 loads per acre, to 18 acres of sandy soil, ploughed under, and the field planted in corn. There was no appreciable benefit derived that year. In 1919 sludge from the tanks was pumped onto this land, about 25 to 30 cubic yards per acre, ploughed under, and corn again planted. This year the yield was increased by an estimated 50 per cent. In 1920 this same 18 acres without any additional sludge and a 10-acre field of poor clay land treated with 20 loads of bed-dried sludge per acre was sown in oats. The yield was about 43 bushels per acre. After harvesting the oats, winter wheat was planted. In spite of frosts, which injured all wheat more or less, the yield was 25 bushels per acre as compared with an average of 15 for the vicinity. In the fall of 1919 and winter of 1920 another field planted in grass was top dressed with sludge direct from the tanks with a fire hose, a total of 1½ to 2 inches being applied. When inspected in June, 1920, the growth was so rank and heavy that it was questionable whether it would stand up to be harvested

No. 9 considered bed-dried sludge superior to the best stable manure. He used it only as a top dressing. After having had a poor wheat crop in the fall of 1919 on land which six years previously was considered worth $40 per acre as against an average value for the locality of $100, he top dressed with sludge, using a manure spreader set at 8 loads per acre, and planted in winter wheat. The yield was 40 bushels per acre, while similar land on the same farm yielded 19½. Following the wheat with clover, he obtained a rank stand which ripened earlier than other clover, but the crop was lost by wet weather. In another field of 49 acres, 9 acres were treated with sludge in 1918, using 20½ loads per acre, and planted with mixed clover and timothy. Two crops were harvested from these 9 acres, the first, so heavy that it "went down" and was hard to cut, gave 30 tons and the second 5 tons, or a total of about 4 tons per acre. On the 40 acres not sludged a total of 42 tons was obtained. This was considered a fair crop, 1½ tons per acre being a good yield for the locality. This field after two years was considered as still being benefited by the sludge. This farmer considers from his experience that sludge is good for grasses, wheat, and corn, but "too strong" for oats, the one crop he tried it on growing so rank that it "went down" before ripening. Oats, he said, can be grown the second year after sludge treatment.

No. 10 also preferred sludge to barnyard manure. He had at the time of the survey a good stand of wheat on land to which he had applied 20 loads of sludge per acre, land which was, to start with, too "poor" to raise any crops at all. (See fig. No. 37.) With raspberries he got an estimated increase of 25 per cent. The crop was not earlier but the berries were bigger.

No. 11 considered sludge nearly as good as manure. He obtained a yield of 25 bushels of wheat per acre on land treated with 15 loads of sludge per acre, but admitted that he had always had plenty of manure and had had equally as good crops from the same field which was "good" land.

No. 12 reserved judgment on the value of sludge as compared with manure, but he gave the results of his tests as follows: Land so "thin" that his neighbors told him he would never get his seed corn back was top dressed with 22 loads per acre. The crop, however, was better than the average on reputed good land. To test the relative value of sludge and manure, he took a field of 30 acres, treating 15 acres with sludge and 15 with manure (the amounts used were not given). The sludged sections, he reported, was superior to the manured section, the cattle preferring the sludged section and eating the grass closer. The poorest part of a hay field with 15 loads of sludge per acre yielded three times the crop of the untreated better section. A tract of shale clay, "too poor for grass" a few years ago, was given 18 loads of sludge and 9 loads of manure per acre. The stand of wheat in the summer of 1920 was, he claimed the best in the vicinity.

No. 13, while not strictly a farmer, used sludge in his private vegetable garden. He was an enthusiastic advocate of sludge for all garden truck, considering it superior to barnyard manure. Nothing had been put on his land for the three years before he applied two loads of sludge to a plot 50 by 80 feet, or about 22 loads per acre. His sweet potatoes were the "best he had ever had." Irish potatoes gave an exceptional yield, beets were better than usual, onions, lettuce, cabbage, peas, beans, cauliflower, parsnips, sweet corn, cucumbers, and tomatoes were good, but he was unable to give any relative figures.

At Rochester, N. Y., the bed-dried sludge from Imhoff tanks was called for by farmers who paid 50 cents per two-horse wagon load. It was intimated that this charge might influence some of the farmers to belittle the value of the sludge to prevent any advance in price.

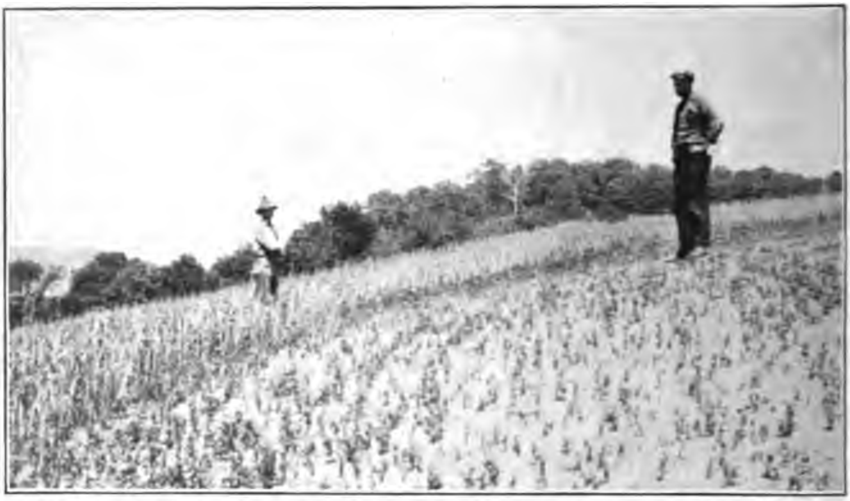

FIG. 35.—WHEAT FIELD AT CANTON, OHIO, SHOWING GROWTH ON SLUDGED AND UNSLUDGED SECTIONS

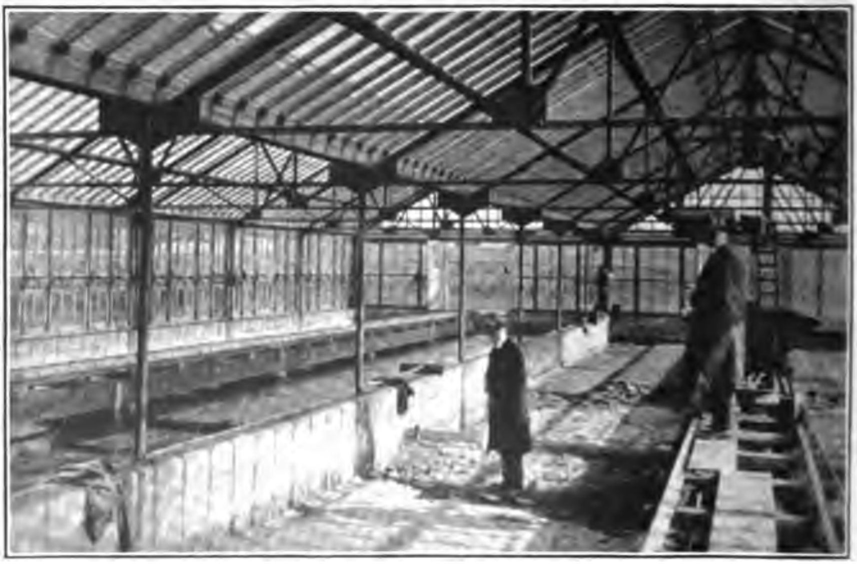

FIG. 36.—GLASS-COVERED SLUDGE BEDS AT CANTON, OHIO

The principal crops raised in this territory are garden truck, peaches, and some grain.

Farmer No. 14 had growing at the time of the survey potatoes and tomatoes, some of each fertilized with sludge and some with manure. He stated, as was obvious on inspection, that the sludged areas looked better than the manured, but the crop had not been harvested. In the experience of this man sludge was beneficial to celery. He considered sludge better than manure for heavy ground containing plenty of moisture, but the manure better for light dry land, sludge on this land burning up the crop.

No. 15 had used sludge for corn, peaches, and garden truck. He stated it was especially good for peach trees, and while on the whole he considered cow manure a better fertilizer, sludge being "too hot" in a dry season, he felt that sludge was a "good fertilizer."

No. 16 had used sludge for corn, tomatoes, and around orchard trees, applying 50 cubic yards per acre, the same as when using manure. He has had good results and considered sludge a "good substitute for manure."

No. 17 in 1919 fertilized three different patches of tomatoes, one each with sheep manure, tankage, and sludge. He was not able to notice much, if any, difference in the yield. In 1920 he was using sludge for early potatoes, parsley, celery, and onions, all of which looked good but had not ripened at the time of the survey. This farmer considered sludge as good as barnyard manure, richer, if anything, but cautioned against using too much.

Four or five more farmers were seen at Rochester. The consensus of opinion was that while, on the whole, sludge was inferior to manure it made a good substitute, being even better on heavy, wet land but likely to burn up the crop on light land or in a dry season. There was also more or less complaint of odors, especially on muggy days.

In Lexington, Ky., a few farmers had used sludge for tobacco and various other crops, but none felt that they had had sufficient experience with it to venture an opinion as to its value. Reports from this plant in 1921 indicate a rapidly increasing use and interest among the farmers.

These experiences are not given as proofs of the value of digested sewage sludge from sedimentation tanks. The personal equation, the lack of specific quantitative results, the absence of properly controlled comparisons with other fertilizers, and other factors, all prevent the statement of any definite conclusions. It is believed, however, that they have a distinct value and are worthy of serious consideration. The following is a general summation of the information obtained:

(1) Of 20 farmers interviewed at four cities, 6 considered sludge superior to barnyard manure, volume for volume (sludge used contained probably 60–75 per cent water); 5 considered it equal or nearly so; 5 considered it inferior, but 3 of the 5 held it to be a good substitute and in wet, heavy ground superior; and 4 ventured no opinion.

(2) With the decreasing production of manure, due to the rapid growth of the use of automobiles, sludge should be looked to more and more as a substitute for local use.

(3) Under certain conditions, the nature and extent of which have never been studied, sludge possesses a value greater than the chemical analyses of its plant food constituents would indicate.

(4) There is a difference of opinion as to the best method of applying sludge, whether as a top dressing or plowing under.

(5) There is more or less odor from sludge, especially when piled, and on muggy days, but this odor does not carry very far and is no more objectionable than many commercial fertilizers.

(6) The weed seeds in the sludge are not a serious objection to its use.

(7) Practical *large* scale experiments should be made with sludge to obtain quantitative data upon which to judge the value of sludge to the soil. In these experiments the "extra" plant food benefits of its use should be given due consideration. The farmers claim to be too busy to make tests, but they want to know among other things: (*a*) The best method of applying sludge—as a top dressing or plowing under; (*b*) the quantity to be used with different soils; (*c*) a direct quantitative comparison of the increase in yield obtained with sludge, barnyard manure, and some commercial fertilizers; (*d*) the lasting effect on the soil.

Hatfield[18] reports a series of fertilizer experiments using various types of dried sludge, dried blood, and some other commercial fertilizers. The experiments were practically all made with pot cultures, the results of which themselves indicated to the authors the necessity for field tests to determine the proper amount of various sludges to be used to obtain the best results. In one series where activated sludge was applied in amount varying from one-half to 3 tons per acre, the best yield was obtained from 1½ tons, with, however, 3 tons giving practically the same results. In a second series one-half ton gave 30 per cent better results than any higher amount up to 20 tons per acre. This was explained by the fact that the pots containing the higher amounts over one-half ton per acre had been fertilized the year before and, on the basis of other tests, should show a decreased yield the second year. Imhoff tank sludge was used at 10 and 20 tons per acre rates, which is probably equivalent to 2 to 4 times that actually used by the farmers interviewed on the survey, most of whom cautioned against using excessive amounts. The large amounts of Imhoff sludge were used to secure a nitrogen as high as other sludges and fertilizers used.

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[18] The Fertilizer Value of Activated Sludge, William Durrel Hatfield. Illinois State Water Survey Bulletin No. 16.

It is not to be expected that bed-dried sewage sludge can be placed on an equal footing with commercial fertilizers or return a profit on expensive methods of treatment, but it is believed that a demand for sludge can be developed among farmers in the vicinity of many treatment plants, that revenues can be obtained from it which will go a long way toward paying for the unavoidable costs of handling at the plant, and that in the agricultural activities of a community there is an economic place for sludge produced by that community.

The production of a prepared fertilizer from sewage sludge appears o be economic only from sludge obtained from the activated-sludge process. In Baltimore a contractor paid the city 82 cents per ton, 0 per cent moisture basis, for bed-dried sludge delivered to his drying plant containing on an average 2 or more per cent nitrogen, which it did about two-thirds of the time. The contract calls for the delivery of sludge at 70 per cent water. At the time of the survey, July, 1920, he contract was near expiration and arrangements had not been made for the future. The superintendent of the plant felt that a well-designed plant averaging 17 tons of dried product per day could break even, and make money at 20 tons per day which is about equivalent to 70 tons of 70 per cent wet sludge. It would appear that this would depend upon the price obtainable for nitrogen, though the superintendent estimated that operating costs would follow nitrogen value. There was no difficulty in disposing of the product, the mar-et for even the 2 per cent nitrogen material being greatly in excess, in 1920, of the output of the plant. Purchasers, it was stated, used he dried sludge as a base or filler for high-grade fertilizers.

In drawing any conclusions from this plant several factors must be onsidered: (1) The plant itself was in poor shape, probably improperly designed in the first place; (2) there was not sufficient sludge to llow uninterrupted operation; (3) the raw sludge had already been artially treated, the moisture having been reduced to about 70 per ent on the beds without expense to the contractor; (4) the market rice of nitrogen was high; (5) the plant as it stands was, according to the superintendent, losing money.

Raymond Wells [19] places 3 per cent as the minimum ammonia ontent (about 2.4 nitrogen) below which any attempt at recovery economically useless.

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[19] Economic Values in Sewage Sludge. Raymond Wells. Municipal Journal and Public Works, Nov. 1919.

From an economic and business standpoint, any goods falling below this rating had better be forgotten and no time wasted on developing methods of handling.

Others have placed 4 per cent nitrogen as a minimum figure for a salable product. Both of these values are higher than can normally be expected in average digested sludges. In spite of the recovery plant at Baltimore, it appears reasonable to conclude, as has already been stated, that the disposal of digested sludges from sedimentation tanks must be accomplished locally.

With the activated sludge process, however, it is reasonable to expect the sludge to contain at least 4 per cent nitrogen and probably more. Upon the economic value of the sludge depends the success or failure of the activated process for large installations. There may be exceptions, such as the necessity for concentrating the plant into a small area, or the demand for an unusually high-grade effluent, but, in general, the cost of the activated sludge process, involving the disposal of tremendous volumes of sludge, will be prohibitive unless the recovery of valuable sludge is able to partially pay for operating expenses.

The present developments of this method are sufficient to justify the statement that the recovery of sludge is feasible and the recovered product will pay for part of the operating expenses, but it is not possible to more than estimate the net cost of the process. Large experimental plants have given valuable data, but there is not in existence in this country any large plant operating under routine conditions at which the treatment and sale of sludge has been demonstrated.

The recovery process, which has already been described, consists of: (1) Concentration, with or without acidification, in sedimentation tanks; (2) partial dewatering by presses or centrifugal machines; (3) heat drying. None of these processes have as yet been standardized. Their feasibility has been demonstrated at testing stations, but they can not be said to have passed beyond the development stage.

Another factor to be considered is the market. The ability of the market to absorb the quantity of sludge which would be produced if many of the larger cities adopted the activated sludge process is yet to be determined. Some of the first plants may find a ready market for their product, but subsequent installations must consider the probable point of saturation.

Reports of the fertilizing value of dried activated sludge have been favorable. For the most part they have been "pot" experiments, but as such they have been fairly conclusive. The experiments of

Hatfield and Bartow[20] in 1915 and of Hatfield[21] in 1918 indicated that activated sludge gave better results than dried blood, gluten meal, or inorganic nitrogenous fertilizer, equivalent nitrogen being used in each case. The application and extension of such experiments to actual conditions on a large scale offers an attractive field of investigation.

The present status of the preparation of sludge for the commercial fertilizer market may be summed up as follows:

(1) The drying of sludge, digested or fresh, from the sedimentation processes for use as a commercial fertilizer can not be considered economically feasible because of the low nitrogen content.

(2) The drying of sludge from the activated sludge process, containing 4 per cent or more of nitrogen, for use as a commercial fertilizer offers attractive possibilities, but its success has not been demonstrated.

(3) The processes of drying are still in the development stage. They have been tried only at testing stations, some of which, it is true, have been of considerable size, but still test units.

(4) Improvements in the drying processes are to be hoped for and may be of sufficient value to establish firmly the principle of the utilization of sludge as commercial fertilizer.

(5) The value of sludge as a fertilizer has been demonstrated.

(6) The extent of the market for dried sludge is unknown.

Sludge digestion tanks.—The purpose of these tanks is to provide a place for the digestion of sludge outside of the sewage sedimentation tanks. Fresh sludge from plain sedimentation tanks, for example, is very foul and hard to handle on sludge beds, and is greatly improved by digestion in separate tanks. Such digestion tanks are also used for sludge from secondary sedimentation tanks, hydrolytic tanks, and, in some instances, septic tanks. As Imhoff tanks have within themselves provisions for this digestion of sludge, separate tanks for this purpose are seldom found with these tanks.

At Alliance the sludge from two plain sedimentation tanks is pumped to the Imhoff tanks which operate parallel with them. These tanks, therefore, serve the double purpose of sewage sedimentation tanks and digestion tanks for plain sedimentation tanks.

At Fitchburg one of the Imhoff tanks is used largely for the digestion of sludge from the secondary sedimentation tanks, being used to treat sewage only occasionally.

Baltimore was the only city visited where special tanks were installed for this one particular purpose, all sludge from the hydrolytic tanks being pumped to these tanks for digestion before disposal.

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[20] The Value of Activated Sludge as a Fertilizer. Hatfield and Bartow, University of Illinois, Bulletin Water Survey Series No. 13.

[21] Loc. cit., p. 184.

These three plants are the only ones surveyed in which sludge was digested in tanks other than those in which it was settled from the sewage, and Baltimore is the only one where such tanks have been designed and built for this purpose exclusively.

Sludge beds.—At 12 of the 15 plants surveyed, the sludge drawn from the tanks was applied to filter beds to dewater it to a condition whereby it could be handled economically.

These beds are generally constructed with bottoms sloping to open tile underdrains, about which is placed a layer of coarse gravel. The material over the gravel grades up to a surface of sand. It is necessary to provide a surface capable of retaining the solids while permitting free passage of water and arrangements below this surface to rapidly drain away the water thus filtered out. Layers of sand one-fourth to one-half inch deep have proved sufficient, but as some sand, probably about one-fourth inch, is lost at each cleaning of the bed it is more economical to provide sufficient sand for several cleanings rather than replace it after each cleaning.

Total depth beyond that necessary to grade the material from sand to 1 or 2 inch stone or gravel around the drains does not appear to be of any particular benefit, as no effort is made to oxidize the effluent in the bed. A 12 to 15 inch total depth with a 2 to 4 inch surface of sand should be adequate.

The idea of covering the beds with a glass structure, such as a greenhouse, to protect drying sludge from rain and to permit of all year operation, was originated at the Cleveland sewage testing station in 1913. Results there indicated that, for local conditions 1 square foot of glass-covered beds was equivalent to 2 square feet of open beds. On the basis of these results, the covered beds at Alliance and Canton, Ohio, were installed. At both the plants the plant operators are advocates of the glass-covered beds, claiming that they are less dependent upon weather conditions and worth the extra money invested.

At Canton records of sludge removed from beds during the period January, 1917, to June, 1918, are available. During this period 39 glass-covered beds and 28 open beds received sludge. During the months of December to April, inclusive, the covered beds received 22 doses against 15 for the open beds, and the sludge was on the beds an average of 32 instead of 43 days. Attention is called to the fact that the time on the beds does not necessarily mean necessary drying period, as sludge may be left on the beds longer than necessary due to lack of labor to clean the beds, etc. During the months May to November, inclusive, the covered beds received 17 applications and the open beds 16, or practically the same. The time on the beds for this period averaged 27 days for the covered beds and 35 days for the open. The total for the entire period of 17 months was 39 doses for the covered beds and 28 for the open beds. The area of both types of beds is the same, but with a bed of each type available the preference was given to the covered beds. Unfortunately, therefore, the data admit of only a relative comparison of the two types of beds.

In the following table the sludge beds at the plants surveyed are arranged for comparison:

TABLE No. 64.—*Sludge beds at plants studied*

	Alliance		Atlanta		Baltimore	
	Glass covered	Open (reserve)	Intrench Creek	Peachtree Creek	Design basis	Operating basis
Total depth (inches)	33	33	13±	13±	12-30	12-15
Depth sand layer (inches)	11±	None.	¼	¼	2-18	4
Underdrainage provided	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Bottom [1]	N.	N.	N.	N.	N.	N.
Tracks on beds	Yes.	No.	Yes.	Yes.	Yes.	Yes.
Total prepared area (acres)	0.235	0.765	0.41	0.41	1.02	5.05
Average depth of dose (inches)	6-10	No record.	8	8	12	7
Average drying period (days)	8-14	No record.	[2] 12	[2] 12	10-21	3-21
Average m. g. d. sewage treatment	2.6		5.0	12.0	14.0	55.0
Population served (thousands)	20.0		30.0	75.0	112.0	520.0
Area per m. g. d. (thousand square feet)	3.91	12.6	3.58	1.49	5.7	4.0
Area per capita (square feet)	.51	1.66	.65	.24	.71	.42
Area per p. p. m. suspended matter per m. g. d. (square feet)	25.7	82.9	33.7	6.5	----------	25.1
Area per p. p. m., suspended matter removed, per m. g. d. (square feet)	47.2	152.0	91.6	9.4	----------	77.0
Is area adequate	Nearly.	Seldom used.	Yes.	No.	----------	----------

	Canton		Columbus	Fitchburg	Lexington	Rochester	
	Glass covered	Open				Brighton	Irondequoit
Total depth (inches)	16	16	8-12	8	12	12	19
Depth sand layer (inches)	15	15	1	8	¼	2	5
Underdrainage provided	Yes.	Yes.	Yes.	No.	Yes.	Yes.	Yes.
Bottom [1]	N.	N.	N.	N.	N.	Puddled clay	N.
Tracks on beds	Yes.	Yes.	Yes.	Yes.	Yes.	No.	[3] No.
Total prepared area (acres)	0.25	0.25	2—	0.42	0.40	0.08	1.78
Average depth of dose (inches)	8	8	8	10	18	9-10	8-9
Average drying period (days)	10-30	10-30	14	29	[2] 9	7	10
Average m. g. d. sewage treatment	4.4		16.8	3.35	2.5	1.0	32.5
Population served (thousands)	60.0		225.0	37.0	28.0	8.0	240.0
Area per m. g. d. (thousand square feet)	4.92	----------	5.18	5.46	6.97	3.36	2.38
Area per capita (square feet)	.84	----------	.39	.49	.62	.42	.32
Area per p. p. m., suspended matter per m. g. d. (square feet)	19.0	----------	25.1	18.4	37.4	33.2	12.7
Area per p. p. m., suspended matter removed per m. g. d. (square feet)	29.4	----------	30.8	23.3	70.4	55.1	34.5
Is area adequate	No.	----------	No.	No.	Yes.	Yes.	Yes.

[1] N=natural ground.
[2] Except during winter season.
[3] Traveling crane places car bodies on bed where desired.

At all the plants listed the sludge is digested either in Imhoff tanks or in special tanks. In the Emscher district, Germany, where the Imhoff tank originated, it was customary to provide 1 square foot of sludge-bed area per three to four persons. This figure was adopted in this country with the Imhoff tank, and used for design. In the above table the sludge-bed areas at 10 plants are given. Of these only 1 provides for less than 0.32 square foot per capita, 5 for 0.32 to 0.51, and 4 for more than 0.51. If the reserve area at Alliance is not considered, only 3 plants provide more than 0.51 square foot of bed per capita.

The Intrenchment Creek plant at Atlanta and the Irondequoit plant at Rochester are the only ones with a factor of 0.33 square foot per capita, and at both these plants the area is considered adequate. At Fitchburg the beds were designed with this factor, but are operating at about 0.5 square foot per capita. Even this has not proved adequate. Sludge is lagooned in low areas, the plant operator estimating that the sludge bed would have to be doubled in area to take care of all sludge. This would mean 1 square foot per capita.

At Columbus, with 0.39 square foot per capita available, the operator stated that three to four times as much was needed. The estimated needed areas at other plants brought the required areas up to an average of 0.6 to 0.85 square foot per capita, with some considerably higher.

On the whole it would appear that 0.33 square foot per capita was, on the average, inadequate and that it should be two to three times that amount.

Downes,[22] reporting on the operation of a plant at Plainfield, N. J., computes from his data a sludge-bed requirement of 0.686 square foot per capita. In discussing the drying period he states:

> It is surprising to find that, in spite of the fact that a coat of sludge 9 inches thick will become spadable in a week or 10 days of good drying weather, under actual climatic conditions, we have averaged only a scant 6 dryings per year. The figures for three years are 5.8, 6, and 5.8 dryings per bed a year.

This illustrates the danger of computing sludge-bed area using an assumed number of cleanings based on average drying periods.

Adequate sludge-bed area means much in the operation of a plant. The only way to effectively overcome foaming in Imhoff tanks is the withdrawal of sludges, and beds should be available when needed for this purpose. With just sufficient bed area, a rainy season or temporary shortage of labor may necessitate carrying overloaded sludge compartments in tanks over the winter.

No part of a treatment plant is less expensive than the sludge beds. Where area is available, the cost of a liberal bed installation is but little more than the minimum requirements. From the table it would appear that under American conditions the majority of the plants require a minimum of 0.5 square foot per capita, and that 0.8 or even 1 square foot per capita is a safer design figure, especially where facilities for lagooning or wasting in low lands are not available, and entire reliance must be placed on the beds.

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[22] Operating Data of Fine Screens and Imhoff Tanks. John R. Downes. Public Works, vol. 50, pp. 370–371.

Sludge is formed from the suspended solids removed from the sewage in its passage through the tank. These removals at different plants have been equated in Table No. 64 with the sludge-bed areas, to obtain the number of square feet available per part per million of suspended matter removed per million gallons daily. These computations are based on the results of analyses made on the survey, which, with possibly one or two exceptions, are believed to be fairly representative of the various plants. The figure for Alliance is very high only if the reserve bed, which is seldom used, is taken into consideration. The result for the Intrenchment Creek plant at Atlanta may be slightly discounted due to abnormal conditions at the time of the survey, and the same may be said to be partially true of the extremely low figure for the Peachtree plant at Atlanta. In this case, however, no proper allowance would bring the figure to within the range of most of the plants, which is between 23.3 and 77. Of the plants at which opinions regarding the adequacy of the sludge were expressed only one, the Irondequoit plant at Rochester, having less than 45 to 50 square feet available per parts per million of suspended matter removed per m. g. d. had sufficient area. Based on these very few results a minimum of about 50 appears to be a safe factor.

The average suspended-matter content of the raw sewage at 12 plants surveyed where sedimentation tanks were used was 177, and the value corresponding for the tank effluents was 75. There was an average removal, therefore, of 102 parts per million. Allowing 50 square feet of sludge-bed area per parts per million per m. g. d., the average minimum requirement of the plants studied is about 5,000 square feet per m. g. d. The average per capita contribution to the sewers for these 12 plants is within 1 or 2 gallons of 100 gallons per day. Using this per capita flow the average minimum sludge-bed requirement becomes 0.5 square foot per capita.

APPENDIX I

DETAILED DESCRIPTION OF TREATMENT PLANTS STUDIED

I. ALLIANCE, OHIO

As described in the body of this report, the sewers contributory to the Alliance treatment plant are divided into the high-level and the low-level systems. The high-level system flows by gravity to the plant, but the low-level, while reaching the plant by gravity, must be pumped to the treatment devices. Before reaching the pumps, however, it is passed through an old treatment plant. As the treatment thus received is probably of little if any value in the operation of the treatment plant proper, it is described elsewhere as part of the sewerage system and this section deals only with the main treatment plant, including, however, the pumping plant for the low-level system.

Pumping plant.—All sewage from the low-level system is received at the treatment plant in a storage basin or pump well. This well is 9 feet 6 inches deep, sloping to 10 feet 3 inches in a length of 24 feet. The width is 13 feet 10 inches. These are inside dimensions. The bottom of the well is 15 feet below ground.

The sewage enters this well through a 1½-inch clear opening bar screen in a small screen chamber from which it passes to the storage well in a 24-inch vitrified pipe. When there is 3 feet of sewage in the well a float trips a Yoemans Bros. (Chicago) control switch and starts one of two vertical Watson induction motors shaft connected to an 8-inch centrifugal pump. Pumping continues against a head of 21 to 24 feet, depending on the depth of the sewage in the well, till the well is emptied, when the float cuts off the current to the motors. The pumping equipment is housed in a brick building.

The volume of sewage pumped is not measured separately, but with the sewage in the high-level or gravity system. In 1916 the designer, Mr. R. W. Pratt, estimated the low-level sewage to be 25 per cent of the total or 0.5 m. g. d. The pumps are stated to operate 20 minutes out of each 50. If the pumps deliver 700 gallons per minute (specification required not less than 700) the volume would be about 0.403 m. g. d. Probably 0.5 m. g. d. is approximately correct.

Entrance flumes.—As originally designed, the plant had three parallel grit chambers preceding the screen. It was found, however, that considerable sludge was deposited, due to checked velocity when the screen was clogging. The grit chambers are, therefore, now used merely as entrance flumes to the plant. The central chamber has been abandoned altogether, one of the others has had a false bottom installed and receives the high-level sewage from a 30-inch sewer, and the third one receives the sewage from the low-level sewers pumped by the plant described above. Both chambers discharge into a common flume to the screen and tanks.

Screen.—This is located in the flume. The screen chamber is rectangular in shape and contains a bar screen with three-fourths inch clear openings set at an angle of 60 degrees with the horizontal. The screenings are raked to a platform at the top of the screen and wheeled away to a dump.

Plain sedimentation tanks.—There are two tanks operated as plain sedimentation tanks. These tanks are (inside dimensions) 132 feet long by 42½ feet wide by a depth sloping from 9 feet at the inlet to 10 feet at the outlet. In addition to the longitudinal slope, the bottoms slope about 9 inches from the sides to the center.

The inlet and outlet channels, 4 feet wide, are contained within the tanks themselves, the entrance to the tank being through openings along the back side of the channel controlled by iron slide or stop gates. Sewage is thus compelled to pass behind and under the channel. A central pier supporting the channel is supposed to diffuse the flow across the cross section of the tank. The outlet has a similar arrangement except that the flow is over adjustable weirs instead of under stop gates. The outlet channel leads to a well from which the effluent is taken to the control houses of the contact beds.

At the outlet end of the tank, in the corner adjacent to the other tank, is located a draining chamber 5½ feet wide by 12 feet long. Three 12-inch sluice gates from each tank open at different elevations into this chamber, permitting the drawing off of supernatant to an old filter bed when cleaning a tank, but without carrying out the scum. The scum can be drawn off the top into the clean sedimentation tank or it can be collected with the sludge.

Each tank has a single 12-inch sludge outlet, toward which the sludge is pushed or washed. The sludge is taken to a 200-gallon ejector set in a pit 7 feet 8 inches wide by 12 feet long by 13 feet 10 inches deep, located at an adjacent contact bed. This ejector discharges into the Imhoff tanks where the sludge is held for digestion.

There are inlet and outlet baffles, the outlet one acting as a scum board.

The total capacity of each tank is 400,000 gallons. The available sewage capacity is somewhat less, probably about one-third million gallons.

Imhoff tanks.—These tanks were constructed inside a third tank of the same size as those already described, the bottom being cut out to obtain necessary depth. As built, the Imhoff tanks are laid at right angles to the old tank inside of which they were built.

There are two unit sets of tanks, each unit consisting of four tanks, or it might be said, a four-flow channel tank, as the four sludge compartments are all connected by openings, 4 by 6 feet, in the walls between them, and through the slots.

The length of each flow channel from the inlet to the outlet weir is 35 feet 2 inches. Each is 12 feet 3 inches wide, and, from the top of the tanks to the slot, about 13 feet 5 inches deep. The flow line is 1 foot, plus or minus, below the top of the tank, depending on the elevation of the adjustable weirs. Three gas vents, each 2½ feet clear width and 24 feet 7 inches clear length, separate the four flow chambers.

The sides of the tank and gas vents are vertical to a depth of 7 feet 3 inches where the bottom slopes start. These bottoms are on a slope of 6 feet 10 inches vertical to 6 feet 1½ inches horizontal. These slopes are in all four directions, so that the slots run lengthwise and across the tank. The slots have a clear opening of about 7 inches and an overlap of about 9 inches.

The inlet and outlet for each channel consist of two 1-foot adjustable weirs. There are inlet and outlet baffles or scum boards consisting of four 2 by 10 boards extending 30 inches below the sewage and located 6 feet from the weirs.

The influent and effluent channels, each 3 feet wide by 3 feet deep, are contained within the walls of the original plain single-story tank. The valves and gates on these channels are arranged to permit reversing the direction of the flow in the tank.

Each unit or set of four flow channels has three digestion chambers with three hoppers, one under each gas vent. These are 22 feet 11 inches long, 15 feet 8 inches wide, and 13 feet deep from the slot overlap to the bottom of the hoppers. The hoppers which underlie the entire digestion chambers are 5 feet deep. The flat bottoms are 2 by 2 feet, giving a slope of 1 to 1.4 to the sloping hopper bottoms.

Around the top of the hoppers is a 1½-inch galvanized-iron water pipe with three-sixteenths-inch holes drilled on 18-inch centers. From this a three-fourths-inch line runs to the bottom of the hopper and turns up at the mouth of the sludge pipe.

The 8-inch sludge pipes, one for each hopper, rise vertically to the top of the tank. At a point 4 feet below the flow line a horizontal pipe takes off and out through the sides of the tank to a sludge gutter, 2 feet wide by 3 feet 10 inches deep.

All sludge or digestion chambers in each unit are connected by openings 4 by 6 feet. This opening is cut right at the top of the hopper.

The sludge from the plain sedimentation tanks, as already mentioned, is pumped to the sludge chambers of the Imhoff tanks for digestion. An 8-inch pipe from the ejector is carried to and turned down into the gas vents of the Imhoff tanks. This arrangement is open to the question as to whether the discharging of large volumes of sludge under high velocity and pressure does not create a positive pressure in the digestion chamber, stirring up sludge and forcing it up through the slots into the flow channels. It is a fact that all flow chambers were continually covered with a heavy scum, which could not be satisfactorily accounted for by deposition of sludge along the bottom slopes of the flow chamber, though this was undoubtedly partially responsible.

The capacity of each flow chamber is 4,120 cubic feet. As designed, the detention period should be two and one-half to three hours, with a lineal velocity of 0.243 foot per minute. The digestion chamber of each unit of three hoppers is 10,490 cubic feet, or about 2,620 cubic feet for each flow chamber. This was considered, when designed, adequate for five to six months' storage.

The available sludge data at the plant confirm the five-month estimate. In the year May, 1919, to April, 1920, 940 cubic yards of sludge of about 80 per cent moisture were removed from the sludge beds. This is approximately 80 cubic yards a month of 80 per cent sludge, or 160 cubic yards, with an assumed moisture in the tanks of 90 per cent. The accumulation per flow channel is therefore about 20 cubic yards per month, or 100 cubic yards per five months, and the sludge storage capacity per flow channel is 97 cubic yards.

The effluent from the Imhoff tanks joins that from the settling tanks, either in the diversion chamber of the contact beds or in the channel to it.

Contact beds.—There are 12 contact beds arranged in 3 units of 4 beds each. Each bed has an area of one-fourth acre, which gives an acre to each unit. These beds were originally built in 1910, but some were more or less modified in 1917.

The following table covers some of the main features of the various beds, as they stand at present:

TABLE No. 65.—*Structural features of contact beds at Alliance, Ohio*

	Bed numbers
Full concrete bottoms	1, 2, 5, 6, 8, 10, 12
Partial concrete bottoms	3, 4, 7, 9, 11
Filtering material washed in 1917	4, 5, 7, 9
Media, 18-inch slag, ¾–1½ inch, 36 inches; cinders, ⅜–¼ inch	4, 5, 7, 9
Media, 48 inches; cinders ⅛–¾ inch	1, 2, 3, 6, 8, 10, 11, 12

In 1910 complete concrete bottoms were placed where such were deemed necessary, while in the others the bottoms were only partially concreted. The beds with complete bottoms were Nos. 1, 2, 6, 8, 10, and 12. In 1917, when the filtering material was taken out from beds Nos. 4, 5, 7, and 9 and washed a concrete bottom was placed in No. 5.

In replacing the washed material, slag 18 inches deep was placed over the underdrainage system, which also was slightly altered. The filtering material in the other eight beds, Nos. 1, 2, 3, 6, 8, 10, 11, and 12, was left as placed in 1910.

The underdrainage system consists of 3-inch tile drains laid 11 feet apart over the entire bottoms, which slope on a 4 per cent grade to two collecting lines, varying in diameter from 8 to 12 inches. These in turn empty into a collecting well at the common apex of each four units, from which it can be discharged onto the secondary sand filters or directly into the Mahoning River.

The distributing system consists of a wooden trough 4 feet wide by 2 feet deep, running from the control house diagonally across the filter for a distance of 36 feet. Within the trough is placed a 12-inch layer of one-half to 1-inch gravel. Sewage leaves the trough through small screens 7 by 6⅜ inches, with one-fourth-inch clear openings, set at 2-foot 6-inch centers at the bottom of each side of the trough, and hence below the gravel in the trough. The pipe extension of the trough is surrounded by 4 feet of the same gravel as in the trough.

The operating control of the beds starts at the chamber receiving the effluent from the tanks. Here hand-operated valves control the lines to the three head houses. In these houses are located alternating siphons, which rotate the dosing of four beds which corner at the head houses. Any one bed can be thrown out of operation, and an automatic release makes overlapping of beds impossible. The installation was provided by the Pacific Flush Tank Co. The houses themselves are low brick structures.

The contact beds are not operated the year around. They are started about the middle of May and discontinued late in November. During the winter tank treatment is all the sewage receives. The filling period depends on the rate of flow of the sewage. It is estimated that 2½ to 3 hours is consumed in filling, about 20 minutes' retention, and 2½ to 3 hours emptying, followed by 4½ to 6 hours' rest.

Intermittent filters.—In the original installation three 1–acre units of fine cinder filters were constructed, later two more have been added, but at present one unit is used for sludge drying, one for treatment of sedimentation tank effluent when the tanks are drained for cleaning, and three for secondary treatment following the contact beds.

These filters are operated only during the hot summer months, as a rule from the middle of June to the end of October. The effluent from the contact beds is collected into a common line, from which it can be discharged through sluice gates onto any one of the three fine filters.

The filtering medium in two of the three filters consists of coarse cinders around the underdrains, then about 30 inches of fine cinders with a surface layer of 2 to 4 inches of sand. The third filter, constructed in 1917, has a slag covering over the underdrains, then a little less than 2 feet of screened cinders, and finally 6 inches of sand. The depth of the coarse cinder or slag layer varies over the filter, at the extreme sides the slope of the lateral drains reduces it to less than 1 foot.

In principle the method of applying the sewage is the same for all filters, wood troughs running across the surface with diagonals reaching to within 10 to 20 feet of the sides. On the two old filters the lateral troughs are spaced 75 feet apart, but in the new filter this is 90 feet.

The collecting or underdrainage system is similar in all, but more complete in the new than in the old filters. In the old ones, the lateral drains, at right angles to a central collector, are spaced about on 38 to 40 foot centers, while in the new filter they are placed on about 9-foot centers. The lateral drains discharge into a central collector which in turn discharges into the Mahoning River, each filter having an independent outlet. Each filter has 5 to 8 ventilators on the margin of the beds, consisting of 8-inch tile extending down and connected with the underdrains.

At the time of inspection these filters had not been put in operation for the season. It was stated that the regular schedule called for the continuous operation of a filter for two days, during which time it received the entire effluent from all the contact beds. This schedule gives a four-day rest after each two days of operation.

Sludge disposal.—As already described, the sludge from the sedimentation tanks is pumped to the Imhoff tanks for digestion. The sludge channel into which the sludge pipes from the Imhoff tanks discharge (see under Imhoff tanks), outlets to a 100-gallon Pacific Flush Tank Co. ejector. This ejector pumps the sludge to the sludge beds. The ejector is housed in a small brick building over a concrete pit, located in one of the contact beds adjacent to the Imhoff tanks. Besides the ejector this building houses the compressor, motor, and air-storage tank for this ejector and also for the ejector pumping the sludge from the plain to the Imhoff tanks.

One of the original fine cinder filters is used for sludge drying. The sludge is received at the drying area through a 6-inch force line from the ejector.

The drying area consists principally of 8 specially prepared beds which have been covered by a glass building of greenhouse construction. The remainder of the 1-acre filter unit is accessible and available, and is used from time to time for excess sludge. No changes, however, were made in the uncovered section to particularly adapt it to sludge drying. In general it has 33 inches of fine cinders over an underdrainage system as described for the intermittent filters. Sludge is applied at one point and allowed to flood over the entire bed.

The 8 special beds are each 20 feet wide by 64 feet long. These beds are arranged in two sets of four each divided by a concrete wall which carries the 6-inch sludge line from the ejector. Valves on crosses in this line furnish the control over each individual bed. Each opening is turned down over a concrete splash plate 3 by 3 feet, which is the only point of application. The four beds of each unit are separated by 9-inch concrete walls. Narrow gage, 24-inch tracks run down the center of each bed. These are laid with the ties flush with the bed so that there is minimum lift from the beds into the cars. All tracks connect to a feed or ladder track to two sludge dumps.

The filtering material consists of the original fine cinder bed material for a depth of 1 foot 8 inches to 2 feet over the drains and a surface of 9 to 13 inches of sand. Over each underdrain is a section of gravel 18 inches wide and about 2 feet deep.

The underdrainage consists of a main 8-inch line, increasing to 10 inches, located near the dividing wall between the two 4-bed units. From this 4 or 8 inch laterals run the length of the beds and are plugged at the ends. Beds Nos. 1 and 3 have one 8-inch main lateral with 3-inch sublaterals across the beds, while beds Nos. 2 and 4 have two 4-inch longitudinal drains with no sublaterals.

Overflows and by-passes.—The first overflow is a weir at the end of the old grit chambers, or, as now used, influent channel. The outlet below the weir is a 24-inch pipe direct to the Mahoning River. As the weir, consisting of two 2 by 6 inch planks, can be drawn, this pipe can be used as a by-pass. The effluent from the tanks can be by-passed around the filters, and this is done during the winter. Finally the effluent from the contact beds can be, and, during certain seasons is, by-passed around the secondary fine cinder filters. To protect contact beds there is an overflow weir in each control house.

II. ATLANTA, GA.

A. INTRENCHMENT CREEK PLANT

Sewage is received at the Intrenchment Creek plant, Atlanta, Ga., in a 4-foot diameter concrete sewer. This empties into a channel 4 feet wide by 4½ feet deep.

Screen.—This is located in the entrance channel. It is 4 feet wide, the width of the channel, and 8 feet long, set at an angle of about 34° to the horizontal. The bars are three-eighths inch, set with a clear opening of 1½ inches. Cleaning is by hand, the screenings being raked to a concrete platform at the top of the screen.

Grit chambers.—This installation follows the screen and consists of 3 parallel chambers each 30 feet long by 4 feet wide. As originally built the bottom sloped up from a depth of 8 feet 6 inches at the inlet to 4 feet 6 inches at the outlet, with a groove down the center of each chamber in which was laid a 6-inch drain to a manhole with an outlet to the creek. This arrangement was later modified by filling the grit chambers with large stone to make a level bottom 4 feet 6 inches deep, and by removing the upper third of the tile drain. Grit is now removed by flushing it to the outlet into the 6-inch drain to the manhole, and thence through an 18-inch line to the creek.

A fourth channel, parallel with the grit chambers, was originally constructed as a by-pass, but it has been filled and, for operating purposes, does not exist.

Measuring device.—The flow of sewage is measured by a Stevens recording float gage, which records the head over the inlet weirs to the tanks. At the time of inspection this gage was out of commission and was said to have been so for the past three years.

Channels to tanks.—Leaving the grit chamber, the sewage enters a 42-inch pipe to the inlet chambers of the tanks. After passing the first chamber, which serves a little over half of the tanks, the 42-inch pipe is reduced to 36 inches.

From the inlet chamber the sewage can be turned into a channel 3 feet wide by 3 feet 9 inches deep from which it flows over weirs into the tanks, or it can be passed under this channel through a 30-inch crossover conduit to an inlet chamber at the other end of the tanks, and thence to a distributing channel for the weirs on that end of the tanks. By this arrangement the direction of flow in the tanks can be reversed. The same channels are used for outlets as well as inlets.

Imhoff tanks.—These consist of 21 tanks arranged in 7 groups of 3 tanks each. The 3 tanks in each group operate in series, but in reality they are more like one tank, as will be explained later.

Each tank is a combination of the rectangular and circular types of construction. The digestion chamber is circular and the walls of this section extend up to the top of the tank. At each end, however, the walls are cut to allow the full width of the settling chamber to extend from one tank to the next in the series.

The over-all maximum inside dimensions of each tank are: Length 31 feet 10 inches, width 25 feet, depth 26 feet.

As stated above, the settling or upper story section of the tank extends beyond the sludge wells. The total length of this section is 31 feet 10 inches and its width 20 feet. The sides are vertical for a depth of 7 feet 3 inches where the bottoms start to slope on a 1 to 1½ slope for a depth of 6 feet 11 inches to a 10-inch horizontal opening slot with a 7-inch overlap. The other slopes forming the slots with the sides are formed by an inverted V partition, with the apex at the center of the tank at the same elevation as the top of the side slopes. Those portions of the settling sections which extend beyond the digestion chamber are connected thereto by an apron sloping from the end of the tank to the end of the slot over the digestion chamber. There are three gas vents, a central chimney rising from and venting the inverted V section, and two side vents. The central vent is 14 feet 8 inches long by 1 foot 6 inches wide. The side gas vents are segments of a circle of 25-foot diameter subtended by a chord 14 feet long. The maximum width is 2 feet 2 inches.

About 16 inches from the inlet and outlet weirs of each unit of 3 tanks are located scum boards extending down 24 inches below the flow line. There are two other "down" baffles, one on each side of the gas vent at the center of the tank, extending down 6 feet below the flow line or the ridge of the bottom partitions. Between the three tanks of a unit there are "up" baffles extending to within 30 inches of the flow line, which is 15 inches below the top of the tanks. The capacity of the flow chamber from the flow line to the slots is 41,000 gallons.

The digestion chamber is circular, 25 feet in diameter and 10 feet 3 inches deep below the overlap of the slots. The sides are vertical for 5 feet, at which point the hopper bottom begins. This is 6 feet 3 inches deep, cone shaped, with slopes of 2 to 1.

The sludge outlet is an 8-inch iron pipe rising vertically from a point just off the center of the hoppers. This pipe extends to the top of the tank through the central gas vent and is capped. Six and one-half feet below the top, a horizontal lateral is taken off across the tank, runs through the side and discharges into a sludge pit, from which the sludge is carried to the drying beds or other disposal points.

A 1-inch lead water pipe is run down to the center of the hopper below the sludge outlet. From this pipe a 1-inch branch extends around the hopper 15 inches from the top, and both lines have one-eighth-inch holes drilled on 18-inch centers. Mr. C. C. Hommon, supervising chemist, stated these pipes were never used and he considered them unnecessary. The capacity below the overlap of the slot is 3,000 cubic feet.

Dosing tank.—From the tanks the sewage passes through a 42-inch conduit to the trickling filter dosing tank.

This tank, for which plans were not available, was said to be of the same design as that for the dosing tank at the Peachtree plant, which is described in detail later in connection with that plant There are three Merritt siphons, two dosing one-half acre each, and one a full acre.

Trickling filters.—There are two units of trickling filters of 1-acre area each. Sewage is received in a 30-inch main distributor from the siphon or dosing tank. This distributor is carried down the center of each filter in a gallery 6 feet wide with an average clear height of 10 feet. From the 30-inch distributor 6-inch laterals are taken off on 11-foot 8-inch centers. These are supported on 3-inch wrought-iron posts spaced on 13½-foot centers, the top of the laterals being 9 inches below the surface of the stone comprising the filter. Every 13½ feet, 6 by 6 by 3 inch tee's are set in these lines and the nozzles, Merritt type, set in the 3-inch openings. By staggering nozzles on adjacent laterals a uniform spacing of 13½ feet over the filter is obtained.

The filtering material consists of Georgia granite 1½ to 2½ inches in size, and the depth varies from 5½ to 6 feet, the difference being caused by the slope of the bottom.

The under drainage consists of 6-inch half tile laid on 9¾-inch centers on a concrete bottom sloping 6 inches in 13½ feet to a 15-inch channel drain molded in the bottom. Over the half tile small concrete slabs 18 by 24 by 3 inches are laid with 1-inch openings to support the filtering material.

The 15-inch lateral drains, laid parallel with the main filter gallery, are spaced on 27-foot centers. They have a slope of one-half foot in the length of the filter, and discharge into a main effluent pipe 24 to 36 inches in diameter located at the lower end of the filter. This pipe drains toward the center and discharges into a 42-inch outfall pipe to Intrenchment Creek.

Over the 15-inch laterals and spaced on 23-foot 4-inch centers are located 8-inch cast-iron ventilators, extending 3 feet 2 inches above the surface of the stone and capped with a cowl. There are no means provided for flushing the distributing or collecting systems.

Sludge beds.—The prepared sludge drying area is 172 feet long by 112 feet 6 inches wide. This is divided by brick partitions into four main beds, each 26 feet wide. The four beds are again subdivided into four smaller ones by transverse brick partitions. The smaller unit is, therefore, 43 feet long by 26 feet wide. The beds as a whole are surrounded by an earthen embankment.

Through the center of each main bed there is a concrete channel 18 inches wide by 12 inches deep, with a semicircular trough of 10-inch diameter molded in the bottom with its invert 1 foot above the surface of the sand in the bed. Sluice gates every 43 feet discharge on both sides of the channel onto 3 by 3 foot concrete splash plates set 2 to 3 inches above the surface of the bed. The concrete channels are connected outside the bed by 8-inch pipes to 2-foot square manholes with sluice gates. An 8-inch vitrified pipe from the Imhoff tanks carries the sludge to the manholes.

Over the channels are narrow, 24-inch gage tracks connected to a ladder track at the lower end of the bed by turntables.

The filtering material consists of one-quarter-inch mortar sand, 2 inches of one-sixteenth to one-quarter inch gravel, 5 inches of one-quarter to 1 inch gravel, and 3½ to 9½ inches of 1 to 2½ inch gravel.

The drainage system consists of two 8-inch main drains running the length of the bed, into which 4-inch lateral drains are connected on 7-foot centers. The bottom, natural ground, slopes both ways from the 4-inch drains to ridges between them. The 8-inch line is laid on an 0.8 per cent and the 4-inch laterals on a 1 per cent grade.

In addition to the prepared beds some sludge has been run onto adjacent fields and low-lying areas.

Sewage pumps.—The location of the plant is such that city water is not available. The effluent from the tanks is used for washing and sprinkling purposes, being pumped by a 2-inch horizontal centrifugal pump direct connected to a 10-horsepower Wagner motor.

By-passes.—By-passes are so arranged that it is possible to cut out either the tanks or filters, or both, or to pass sewage around the entire plant, which it is customary to do at times of storms.

Miscellaneous.—As originally built, roughing filters were provided between the tanks and trickling filters. These, however, have never been used and for operating purposes are practically nonexistent.

B. PEACHTREE CREEK PLANT

Sewage is received at the Peachtree Creek plant, Atlanta, Ga., in a 4-foot diameter concrete sewer. This empties into a channel 5 feet wide by 5½ feet deep.

Screen.—This is located in the entrance channel. It is 5 feet wide and 10 feet long, set at an angle of about 34° to the horizontal. The bars are three-eighths inch, set with a clear opening of 1½ inches. Cleaning is by hand, the screenings being raked to a concrete platform at the top of the screen.

Grit chambers.—This installation, following the screens, consists of three parallel chambers each 30 feet long by 5 feet wide. As originally built the bottom sloped up from a depth of 9 feet 8 inches at the inlet to 5 feet 6 inches at the outlet, with a groove down the center of each chamber in which was laid a 6-inch tile drain to a manhole with an outlet to the trickling filter drains. This arrangement has been modified by covering two-thirds of the drain from the inlet with slag, removing one-third at the outlet, and leveling the bottom with large stone and sand to give a uniform depth of 5 feet 6 inches. A 12-inch pipe was laid from the manhole, receiving drainage from the 6-inch tile to the creek. With these modifications it is now customary to clean the grit chambers by flushing the deposits direct to the creek.

A fourth channel parallel with the grit chambers was originally constructed as a by-pass, but this has been filled and, for operating purposes, does not exist.

Measuring device.—The flow is measured by a Bristol recording gage, actuated by a McDougal Dexter compressed-air device, reading the head over the weirs of the Imhoff tanks.

Channels to tanks.—Leaving the grit chambers, the sewage enters a conduit to the tanks. This is a 48-inch line to the inlet chamber of the first battery of 12 tanks, and continues thence, reduced to 42 inches, to the inlet chambers of the second battery of 12 tanks and the third battery of 6 tanks.

From the inlet chambers the sewage can be turned into a channel, 3 feet wide by 3 feet 9 inches deep, from which the weirs to the tanks are fed, or it can be bypassed under this channel through a 30-inch crossover conduit to another chamber at the other end of the tanks and thence to a distributing channel for the weirs on that end of the tanks. By this arrangement the direction of flow in the tanks can be reversed. The same channels are used as outlets as well as inlets.

Imhoff tanks.—This installation consists of 30 tanks arranged in 10 groups of 3 tanks each. The 3 tanks in each group operate in series, in reality as one tank, except that there is a distinct demarcation between the tanks.

The individual tanks are of the same design as those at the Intrenchment Creek plant. Reference is, therefore, made to the description at that plant, noting, however, the following differences in dimensions. The total tank length—that is, the length of the chambers—is 32 feet 2 inches instead of 31 feet 10 inches, and the central gas vents are 6 feet instead of 14 feet 8 inches long, the width being the same.

Dosing tank.—A 42-inch conduit, increasing to 48 inches, takes the tank effluent to the dosing tank of the trickling filters. The sewage enters the receiving channel of this tank through two 36-inch pipes. The dosing tank, which is divided into three sections, has a total inside length of 55 feet, width of 21 feet, and depth of 9 feet 2 inches. The receiving channel extends the entire length and is 3 feet wide by 5 feet deep, the bottom being 4 feet below the high-water level in the discharge chambers.

The sewage flows from the inlet channel over three 5-foot weirs into three separate though connected siphon chambers. Any of the weirs, however, may be blocked by stop planks, the pipe connection between the chambers closed, and the section of the filter controlled by that siphon put out of operation.

The central siphon chamber is 20 feet by 17 feet 6 inches at the top with two sides sloping in to give bottom dimensions of 6 feet by 17 feet 6 inches. The two side chambers are 20 by 18 feet at the top with three sides sloping to a bottom 11 by 6. All have a maximum inside depth of 9 feet 2 inches, with the high-water line 7 feet from the bottom. These dimensions give approximate total capacities of 2,450 cubic feet and available dosing volumes of 12,500 gallons for all chambers.

The discharge is through 24-inch Merritt siphons into two 42-inch and one 30-inch conduits to the filters.

Since installed as described above modifications have been made in the method of control of the siphon discharge. Details of these changes are not included, as their effect on the operation of the treatment plant and the efficiency of the processes does not appear to be of sufficient importance to warrant such description.

Trickling filters.—The trickling-filter installation consists of 2½ acres. It should be noted here that the filter installation has a rated capacity of only half that of the Imhoff tanks. The former were designed for an average 5 m. g. d. flow, while the tanks were designed for a 10 m. g. d. flow. It is customary to by-pass around the filters all tank effluent in excess of 5 m. g. d. The details of design for any unit, except for a few minor dimensions, are the same as for the trickling filters at the Intrenchment Creek plant. Reference is here made to that description, note being made of the following differences:

(1) Peachtree filtering material 1½ to 2 inch stone instead of 1½ to 2½ inch.
(2) The distributors are 7 instead of 9 inches below the surface of the stone.
(3) The main collector is 24 inches throughout.
(4) There are three 30-inch outlets to the stream instead of one 42-inch.

Sludge beds.—The sludge-drying area is identical in design and dimensions with that described at the Intrenchment Creek plant. Reference is made to that escription.

The sludge-drying area is about one-third sufficient for the plant. A large mount of sludge is discharged on large low-lying flats across the creek. Some also discharged into the creek at times of high water.

By-passes.—At the inlet manhole to the plant an overflow weir, adjusted to 12 g. d. flow, by-passes all above that amount. During heavy storms this weir pulled and the entire flow by-passed. After passing the grit chambers either e tanks or filters or both can be by-passed, or a portion of the tank effluent be sent to the filters and the remainder by-passed. This last is, as described ove, the normal method of operation.

Laboratory.—All laboratory work for the three plants is done at the Peachtree t. Here adequate laboratory facilities with sufficient apparatus to perform ecessary analyses are provided.

esidence.—An attractive frame residence is provided at the plant for the rintendent of the three sewage disposal plants.

iscellaneous.—As originally constructed, roughing filters were provided een the tanks and the trickling filters. These devices, however, are not and for operating purposes are nonexistent.

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rt of the sewage received at the treatment plant has passed through the s at the pumping station. It is, however, mixed with unscreened sewage outfall sewer.

ens.—The outfall sewer at the entrance to the treatment plant is 12 feet es wide by 11 feet high, with rounded top and slightly curved bottom. ischarges into an entrance chamber 18 feet 6 inches long, 12 feet 3 inches t the inlet, flaring to 25 feet 6 inches wide at the outlet, and 12 feet deep inlet, sloping to 14 feet at the outlet. At the outlet a baffle or column the chamber to allow two openings 7 feet wide into the two compartments screen chamber. These openings are provided with stop planks.

screen chamber is 49 feet 3 inches long, 25 feet 6 inches wide, and 14 feet The screens are of the bar type placed nearly parallel to the line of flow. uent or outside channel for each screen is 10 feet wide at the inlet but to 4 feet at the outlet, as the screens are not exactly parallel with the This arrangement gives a central or effluent channel 5 feet 6 inches wide nlet and 15 feet 6 inches at the outlet. The central channel is divided into two equal sections by a middle T shaped wall. Both discharge through stop-plank controlled openings into separate chambers from which feed lines lead to the meters.

These chambers are each 23 feet 6 inches long, 12 feet wide, and 14 feet 6 inches deep. They are separated by an 18-inch wall, but connected by two 3-foot 6-inch square openings cut through this wall. It is thus possible to use both sides of the screen chamber to feed the same meters. This screen chamber installation is complete for future growth of the plant.

The screens themselves are 49 feet 6 inches long by 11 feet 7 inches high, but set at a slope to give a vertical height of only 11 feet. They are made of one-half by 1¼ inch bars spaced to give a clear opening of seven-eighths inch.

The screens are cleaned by hand, the screenings being raked up to the platform by the top of the central T wall. From here the screenings are taken in a wheelbarrow to a platform just outside the building which covers the screen chamber. Farmers take them away from the platform, paying a fixed price per load. The building covering the screen chamber is of attractive concrete construction, with ventilation through the roof.

Venturi meters.—Feed pipes to the meters are taken off the north chamber only. The openings from the south chamber are blocked pending future enlargement of the treatment plant as a whole.

From the north chamber, five valve-controlled 42-inch cast-iron pipes are taken to the meter house, which lies just north of this chamber. Each line feeds a 42 by 21 inch recording Venturi meter. Three of these measure the flow to the three hydrolytic tanks, the fourth the flow to the Imhoff tanks, and the fifth is idle pending further installation.[1]

Hydrolytic tanks.—There are three hydrolytic tanks, each having a total inside length of 417 feet 8 inches.

The sewage from the meter house is taken to the tanks in 42-inch diameter conduits, one for each tank. These enlarge to 6 feet in diameter just before entering the tank at the center of the inlet wall. They discharge against a deflector wall that runs across the tank 3 feet from the end wall. This deflector wall has six 9-foot wide openings spaced on 8-foot centers.

Each tank is divided transversely into two sections separated by a curtain wall which extends up from the bottom 6 feet. Three feet ahead of this wall is a scum or baffle extending down 1 foot below its top.

The inlet section is 103 feet 11 inches long by 101 feet 9 inches wide by 10 feet 6 inches to 11 feet 9 inches deep. The bottom slopes into three longitudinal hoppers, each 68 feet 3 inches long, by 28 feet wide at the top and 2 feet wide at the bottom, and 1 foot 3 inches deep. Down the centers of these hoppers 2-foot semicircular bottom drains lead on a 2.75 per cent grade to a 32 by 48 inch sludge drain under the curtain wall.

The outlet section is 313 feet 9 inches long by 101 feet 6 inches wide by 13 feet to 15 feet 6 inches deep. The bottom slopes similarly to that in the inlet section except that there are only two instead of three hoppers. These hoppers are 204 feet 11 inches long at the bottom by 50 feet 9 inches wide at the top and 2 feet wide at the bottom. The drain channels slope from both ends to a cross drain located 54 feet 8 inches nearer the curtain wall than the outlet wall. These cross drains lead to an egg-shaped sludge conduit under the dividing walls between two tanks. The final outlet is through six 24-inch circular sluice gates into an effluent channel 12 feet 6 inches square. Three feet in front of the sluice gates is a scum board extending down 6 inches below the bottom of the gates or 7 feet 6 inches from the top of the tank.

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[1] One hydrolytic tank and meter has been added subsequent to the survey.

Quite extensive arrangements are provided for flushing the tanks. Along the top of the walls of the tanks there are water mains with flushing hydrants.

The sludge conduits under the curtain wall and those under the dividing walls between two tanks lead to pump wells 7 by 3½ to 4 feet in plan. From these, 10-inch De Laval centrifugal pumps with special impellers, shaft connected to 35-horsepower Fort Wayne motors, pump the sludge to sludge digestion tanks. There are two such pumping installations for the hydrolytic tanks, each designed to serve two tanks.

In operation, two hydrolytic tanks run in parallel, with the third idle. At the time of the survey over 95 per cent of the entire flow was being treated in these tanks. A tank is operated until the analyses show its settling efficiency to be materially below normal when it is shut down and allowed to lie idle for one or more days. The liquor between the scum and sludge is drawn off and pumped to one of the operating tanks, and the sludge and scum remaining is then pumped to sludge digestion tanks. Lack of adequate sludge storage tanks has compelled the operation of the hydrolytic tanks for longer periods than would otherwise be desirable, and this has resulted in the accumulation of very heavy sludge and a dry scum to which it is necessary to add considerable water before it can be pumped.

The capacity of each hydrolytic tank is about 4,000,000 gallons, but all this capacity is not available for sedimentation since the accumulation of scum and sludge reduces the volume. Efforts to determine the detention period by the color or dye method have been successful. It was estimated that the detention period averages from three to three and one-half hours.

Imhoff tanks.—The Imhoff tank installation consists of 28 circular radial flow tanks. They were originally designed for a downward and outward flow, but are being converted to a horizontal and outward flow.

A 42-inch conduit from the meter house supplies all the tanks, which are arranged in two rows of 10 tanks each and a third row of 8 tanks. The conduit discharges into an entrance chamber which flares from 42 inches to 6 feet wide and divides into 5 channels which run between the two 10-tank rows. The two outside channels are 9 inches wide, feeding the first 4 tanks on each side, the next two are 15 inches wide, feeding the second 4 tanks, and the middle channel is 18 inches wide, feeding the last 2 tanks. All are 24 inches deep. For the row of 8 tanks a 26-inch wide channel is taken off the influent chamber, run around a 10-tank row and turned to parallel the far side of the 8 tanks. This 26-inch channel divides into two channels, 9 by 15 inches, each supplying 4 tanks. All channels and all tank inlets are controlled by stop planks.

The inside diameter of the Imhoff tank at the top is 39 feet. The sides are vertical for 3 feet 6 inches. They then slope in on a 1 to 1¼ slope to form an 8-inch slot with a baffle wall, to be described later, and continue past the slot to give an 8-inch overlap.

Each tank has a central gas vent, with an inside diameter of 5 feet 4 inches. From this vent the baffle forming the other side and bottom of the flow channel slopes out to meet the insloping outside wall.

Sewage enters the tank from the influent channel by a trough 12 inches wide and 18 inches deep which runs across the tank to a 12 by 16 inch channel circling the gas vent. This orginally discharged into the tank through openings in the bottom, but it is being changed to discharge over the channel wall. The flow is, therefore, radial across the tank to a collecting trough 12 inches wide by 20 inches deep, circling the tank, into which the sewage flows over notched weirs. Four feet from the collecting trough a circular galvanized-iron baffle 26 inches deep is hung so that its bottom is about 22 inches below the crest of the notched weirs on the effluent collector.

The effluent collector trough discharges into an effluent channel 3 feet wide and of varying depth. These channels are located diametrically opposite the inlet channels. They lead to and discharge into the effluent conduit from the hydrolytic tanks.

The total depth of the flow chamber from the top of the tank to the apex of the slot is 13 feet 6 inches, but, as the crest of the outlet weirs is 10 inches below the top of the tank, the available depth from the crest of these weirs is 12 feet 8 inches. The designed available capacity is 8,520 cubic feet or 63,900 gallons.

The sludge digestion chamber below the overlap of the slot enlarges from a diameter of 21 feet to 23 feet in a vertical distance of 1 foot 4 inches. The walls are then vertical 5 feet 8 inches to the top of the hoppers. These have a depth of 5 feet 3 inches, the bottoms having a 2 to 1 slope. The sludge outlet is an 8-inch pipe starting over the center of the hopper and sloping up to the top of the tank, passing through the flow chamber. About 5 feet below the flow line a branch is taken off horizontally, and run through the tank wall to discharge into a tile line to the sludge beds.

The capacity of the sludge compartments below the overlap of the slot is 3,612 cubic feet, designed to give a storage of 6 months on a basis of 1 cubic foot per capita for the estimated population of 4,000 to be served by each tank.

At the time of the survey, only 5 of the 28 tanks were operating and these as test units. The tanks, as originally designed, did not give satisfaction. There was considerable foaming and excessive scum formation in the settling chambers in spite of frequent squeegeeing of the walls and sloping bottoms. In addition, when operated in parallel with the hydrolytic tanks, the higher loss of head in the Imhoff tanks and inlet and outlet channels diverted the entire sewage flow through the hydrolytic tanks as soon as the head in the outfall sewer dropped below a certain level, which it did for about four hours each day. When the flow increased, the water level was built up in the hydrolytic tanks and backed from the main effluent channel through Imhoff tank effluent channels into the tanks themselves, stirring up the scum in these tanks.

These tanks were taken out of service in June, 1917, the sewage flow then being too much for one hydrolytic tank and the Imhoff tanks and too little for two hydrolytic tanks with the Imhoff tanks. Several of the Imhoff tanks have been run as test units, and, as a result of these tests, all the tanks are being slightly remodeled. The flow line is being raised to prevent back flow from the effluent channels, the number of weirs on the effluent collecting channel in the tank reduced from 52 to 35 and the flow changed to a horizontal radial direction instead of upward and outward.

Fine screens.—The main effluent channel, carrying the effluent from both the hydrolytic and the Imhoff tanks, discharges into revolving fine screens. These screens were installed to remove solids in the tank effluent which clogged trickling filter nozzles.

Three of these screens were in service at the time of the survey and a fourth was being installed. The original installation consisted of two screens made of cast iron and steel, weighing about 10 tons. Their weight was too much to secure trunnions capable of standing up for more than about 10 days. They were, therefore, abandoned and the present type, designed by Mr. J. J. Neal, adopted. The frames of these screens are made of oak with iron bracing, and they weigh complete only 1½ tons. They are 12 feet in diameter and 10 feet long, covered with 24-mesh Monel metal cloth. Around this cloth a 9 or 10 gage galvanized-iron wire is wound in spiral.

The sewage enters the inside of the screens, which are set with a horizontal axis of revolution, and flows out through the Monel metal cloth. Cleaning is done at the top point of revolution where a spray of final filter effluent is directed onto the outside of the screen from a 0.008-inch slot in a pipe. The screenings drop into a trough which carries them to an unused Imhoff tank where they are settled.

These screens have proved very efficient, reducing the filter nozzle cleaning from 37 to 141 per cent daily down to 5 to 15 per cent. Each screen can handle over 30 m. g. of sewage daily with a loss of head of 1 to 6 inches. It was stated that the Monel metal cloth lasted about one year, the wire winding about three months, and the screen frame and bearings about five years, when it is necessary to make extensive repairs to moving parts.

Filter-control house.—The effluent from the screens passes to the filter-control house in a covered conduit 12 feet 6 inches wide by 13 feet deep. Here it enters a storage chamber, 48 feet 8 inches long by 25 feet wide by 23 feet deep, through three openings, 5 feet wide by 2 feet 6 inches deep, cut in the common wall between the main effluent channel and the storage well, the bottom of the openings being 5 feet below the floor level above the storage well. These openings were originally equipped with float controlled gates to maintain a constant level in the storage well, but this automatic feature has been abandoned, and the flow into the storage well is now regulated by hand within established limits.

There are twenty 18 by 27 inch cast iron pipes, ten of which are controlled by 18 by 27 inch sluice gates in the storage well. These are set in the side of the storage opposite the inlet. These are arranged in two batteries, each battery having two rows of 5 pipes each, one above the other. Only one battery is in use as the filter installation does not, as yet, require more than 10 lines, each of which provides for 3 acres.

With the sluice gates from the storage well open, the flow through to the filters is controlled by butterfly valves in the ten 18 by 27 inch lines. These valves are actuated by a motor through friction disks. Just inside the building the 18 by 27 inch cast-iron pipes discharge through increasers into 36-inch concrete conduits to the filters.

Trickling filters.—This installation consists of 10 units of 3 acres each, a total of 30 acres. The ten 36-inch feed lines from the control house are carried down along one end of the filter installation, all cast in one block of concrete. They are arranged in two rows of five each, one row on top of the other. The filters lie in 5-row 2 units each. After two rows have been passed the 36-inch circular conduits are converted into a rectangular shape, 2 feet 6 inches wide by 4 feet deep.

At the center of each row, two feed lines are taken off, one for each filter unit in that row, and carried down the center of the filters in a double gallery, 12 feet 4 inches wide by about 7½ feet high. This gallery is divided by concrete partitions into three sections, the central one, 4 feet 4 inches wide, carrying the feed lines, and the two side ones, each 4 feet wide, for inspection galleries.

From the main distributors in the galleries 6-inch lateral distributors are taken off on 15-foot centers, each supplying 11 nozzles. Some of the laterals are of cast-iron pipe while others are of vitrified terra-cotta pipe incased in concrete. All are supported by small concrete posts, the centers of the laterals being about 2 feet 9 inches below the surface of the stone. Beyond the last nozzle the lateral is reduced to a 3-inch cast-iron line, and extended 6 feet to a flushing gallery, 4 feet wide by 7 feet high, where it terminates in a valve. This provision for flushing was used at first, but the present method is to flush through the end risers by removing the nozzle. By flushing through the valve into the gallery it was found that the sediment splashed back into the small underdrains which vent into the gallery.

The risers for the nozzles are 3-inch cast-iron pipe extending above the stone so that the top of the nozzle is 6 inches above the stone. The filter nozzles are on

15-foot centers, but they are not staggered on adjacent laterals so that the diagonal distance between nozzles on two laterals is about 21 feet 2½ inches.

There are on an average of 583 nozzles for each 3-acre unit. The Merritt nozzle predominates with 4,630 nozzles as against 1,200 of the Taylor cloverleaf type.

The filtering material consists of 8½ feet of trap rock of 1 to 2½ inch specified size. As is usually the case, however, there is some stone well under the 1-inch size.

For drainage, the concrete bottom of the filter is molded into channels 4 inches deep by 6 inches top width, on 11-inch centers. These run parallel with the distributors and drain with a one-half per cent slope from both the main double gallery and the single flushing gallery to a main drain midway between these galleries. This drain is 3 feet wide by 9 inches deep at its upper end with its bottom sloping on about a 0.3 per cent grade to a depth of 3 feet 4 inches at its lower end, where it discharges into the effluent channel. A manhole is provided at the center of this drain for inspection and flushing.

Over the lateral drains molded in the bottom are laid 10 by 20 inch vitrified plates with 6 by one-half inch slots on 3½-inch centers to form the level bottom upon which the stone is laid.

As will be described later, the water level in the effluent channel rises during part of the day 2 or more feet above that originally intended. This backs the water into the filters, which operate during these periods of high-water level with underdrains and part of the filter stone submerged.

At the present time (1920) the entire installation of 30 acres is not needed to take care of the sewage flow. All beds are ripened and kept in condition by being put into service for a short period every day, but the main load is carried by 12 to 24 acres which are put in or taken out of service to correspond with the variations in flow. The average rate of treatment is about 2.83 m. g. per acre per day.

Trickling filter effluent channel.—This lies along the lower end of the rows of filters, and receives the sewage from the main underdrains of the filters. Where it starts at the outlet of the first filter drain it is 3 feet wide by about 4 feet 10 inches deep. Its bottom slopes at a 0.25 per cent grade, thereby increasing the depth, and the width is gradually increased through the entire length of the filter installation, so that at the end of the filters the channel is 10 feet wide by 8 feet 10 inches deep. Before reaching the secondary sedimentation tanks this depth was originally reduced to 7 feet 8 inches, but later due to friction in the mixing channel, described below, it was necessary to build up the walls 1 foot. This produced the flooding of the filter underdrainage already mentioned.

Disinfection.—It was originally contemplated, when designing the plant, that the filter effluent be disinfected with chlorine. A part of the effluent channel was therefore designed to act as a mixing chamber after adding the chemical. Where the effluent channel makes a right-angle turn to the secondary sedimentation tanks its width was increased from 10 to 25 feet for a distance of 144 feet and then narrowed down again to 10 feet. In the wide section, baffle walls divert the sewage from one side to the other four times.

Disinfection has been tried only once since the plant was put in operation, and then only for experimental purposes. Arrangements have been made for by-passing part of the flow around the mixing chamber.

Secondary sedimentation tanks.—There are two secondary sedimentation tanks, each 272 feet long by 290 feet wide, with one side wall on a slope, the other being the vertical division wall between the two tanks. The depth varies from 10 to 12 feet, the bottoms sloping to form two shallow hoppers with central drains running to a pump well in the dividing wall.

The final effluent channel from the filters runs the entire length of one end of the tanks, and was designed to feed into them through seven 24-inch sluice gates, set flush with the bottom of the channel and spaced on 40-foot centers. These have proved inadequate, necessitating the cutting of additional openings through the wall between the channel and the tanks.

The outlet of the tanks is over a weir, extending the full width of the tanks and discharging into a final effluent channel, 10 feet wide by 6 feet 8 inches deep.

The tanks have a total capacity of 760,000 cubic feet each, or nearly 5,700,000 gallons.

Hydroelectric plant.—The effluent from the secondary sedimentation tanks is taken to the power house where it is used to generate electric current used for all purposes over the plant. There is available a head of about 18 feet on two Morgan-Smith water turbines, shaft connected to two 110 kilowatt Fort Wayne generators. In reserve, there is an 85-horsepower, four cycle, Nash gasoline engine. Since 1916 it has always been possible to generate ample power with the turbines. The power generated is used for the sludge pumps, the fine screens, the butterfly valves on the trickling filter feed lines, pumps to provide the water supply and others to pump purified sewage for flushing purposes and general use around the plant.

Final effluent conduits.—From the hydroelectric plant, the final effluent is carried in two 5-foot diameter wood-stave pipes 2,500 feet long extending submerged into Back River.

Sludge digestion tanks.—There are two types of sludge digestion tanks, the rectangular type of which three were built as part of the original installation and one in 1921, and the circular type of which 16 were constructed in 1914 in order to give additional storage space.

Three of the rectangular tanks lie adjacent to the hydrolytic tanks. Each tank is 101 feet 6 inches wide by 138 feet 4 inches long by 13 feet 6 inches to 15 feet 6 inches deep. The bottoms slope from both sides and from two ridges on a 11 to 1 slope to 3 longitudinal drains. They also slope from the two ends on the same 11 to 1 slope to these drains. These drains have a 2 per cent grade to sluice gates which vent into a manhole, from which a 32 by 48 inch egg-shaped drain on a 6.44 per cent grade leads to a pump well at the center of the south wall of the three tanks.

The sludge is pumped from the hydrolytic tanks by pumps which were described in discussing hydrolytic tanks. The pipes are carried on the north wall of the sludge tanks which is also a south wall of a hydrolytic tank. The sludge is discharged on the surface of the digestion tanks.

After digestion the sludge is pumped from the well already mentioned to the sludge beds by a pumping installation identical with that described under the hydrolytic tanks.

As the sludge becomes very heavy in these tanks it is frequently necessary to use considerable flushing water to handle it by the pumps. Each tank has a capacity of about 203,000 cubic feet.

In 1914, 16 additional sludge digestion tanks were installed south of the filters and east of the sludge beds existent at that time.

These tanks have an inside diameter of 38 feet. The walls are vertical to a depth of 15 feet below which there is a conical hopper 9 feet 6 inches deep, making the total depth of the tanks 24 feet 6 inches, and giving a total capacity of 20,600 cubic feet per tank or roughly 330,000 cubic feet for the 16 tanks.

The sludge is pumped to the digestion tanks in a 12-inch line from the hydrolytic tanks. From this line, an 8-inch pipe is taken off for each digestion tank. This pipe enters a tank near the top of the hopper and then turns up to discharge near the center about 8 feet from the top.

Digested sludge is removed by the hydrostatic pressure over the outlet of the tank. An 8-inch line starting about 2 feet above the center of the hopper runs across the tank, passes through the side wall about 10½ feet from the top, and discharges into an open sludge channel 12 inches wide by 18 inches deep, from which it can be drawn off through stop gates on to the sludge beds.

In 1921 another sludge digestion tank was built, having a capacity of 232,500 cubic feet. This tank is 150 feet long, and 86 feet wide, inside dimensions. The depth of the tank at the sides is 16 feet 3 inches, and at the center 21 feet 3 inches. The undigested sludge enters at both ends near the bottom through a 12-inch cast-iron pipe. There are 6 manholes along the walls, each with 1 outlet pipe, and 3 inlets placed at different elevations. Each inlet is provided with a 10-inch circular sluice gate. The outlet pipes connect with a rectangular concrete channel 12 inches wide and 18 inches deep through which the sludge flows by gravity to the drying beds. A concrete walkway, 30 inches wide, is provided along the top of the tank in order to facilitate the operation. All of the sludge is removed by gravity to the drying beds.[1]

Sludge beds.—There are four separate sludge bed areas, two of these are used for sludge from the sludge digestion tanks, one for sludge from the Imhoff tanks, and one for sludge from the secondary sedimentation tanks.

The first bed installed was 400 feet long by 100 feet wide. It consisted of 30 inches of sand over about 6 inches of gravel, the gravel, however, thinning out toward the edges of the bed. The 30 inches of sand was considered too much for satisfactory drainage, and the depth has been reduced to about 18 inches. The bottom slopes from both sides toward the center on about a 1 per cent slope which is increased for the last 10 feet nearest the center. On the slopes 4-inch drain tile are laid on 24-foot centers with open joints. These connect into an 8-inch vitrified line running through the center the full length of the bed on a 0.25 per cent grade and discharging into a marshy area south of the plant.

Subsequent to the survey a pumping station has been provided to pump the water which runs off from the sludge placed on the drying beds. This station is provided with two 5-horsepower vertical motors direct connected to two 2-inch centrifugal closed impeller sump pumps, each with a capacity of 160 gallons a minute. The water is pumped through a 4-inch cast-iron main to the effluent channel of the primary sedimentation tanks from which it flows through the trickling filters and the secondary sedimentation tanks. Each pump unit will work automatically.[1]

Sludge is applied to the bed at three points from either the 12-inch line from the rectangular digestion tanks or from a 12 by 18 inch open channel from the circular digestion tanks. It is run down a short concrete chute into a small box with its top level with the bed and from this it floods over the surface.

In 1914 another bed of the same area was built on the other side of the 12-inch feed line. Its area, however, was subdivided into nine beds of different widths, and the bed itself is of a different construction. The sand layer is 4 inches deep and rests on a layer of graded gravel 8 to 11 inches deep, except over trenches where it covers the drains. These drains consist of a 4-inch tile down the center of each bed, starting 12 feet from one end and discharging into a 6 to 8 inch main drain, which runs across all beds 12 feet from the other end. This main drain has a grade of 0.5 per cent and discharges into the 12-inch line already described.

Sludge is applied onto splash plates at the center of one end of the beds from an open channel, 12 inches wide by 18 inches deep, into which the circular digestion tanks discharge. Sludge can also be taken into the channel from the 12-inch line from the rectangular digestion tanks.

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[1] Comment by the Division Engineer of Sewers, Baltimore, Md.

These two beds are considered as one area. A second area consists of two beds built in 1914, one on each side of the circular digestion tank installation. These beds are in design similar to the second bed described above. The filtering material and underdrains are the same, but the beds are 468 feet long by 150 feet wide, divided into 18 beds, 26 by 150 feet.

A third area, also built in 1914, is adjacent to the Imhoff-tank installation and is available for these tanks only. This area consists of two beds: One, 404½ feet long by 75 feet wide, divided into 15 beds, 75 feet long by 26 feet wide; and the other, 189 feet long, by 75 feet wide, divided into 7 beds, also 75 by 26 feet.

The material in the bed consists of 4 inches of sand over 8 to 11 inches of graded gravel. The underdrainage is similar to the other beds built in 1914—a central 4-inch drain on a 1 per cent grade discharging into a 6 to 8 inch drain on a 5 per cent grade across all the small beds.

Sludge flows in pipes by gravity from the Imhoff tanks to an open channel along the beds; from this channel it is discharged onto splash plates.

The fourth area is adjacent to and for sludge from the secondary sedimentation tanks. This area is 500 feet long by 150 feet wide, with two subdivisions. The bed consists of 12 inches of sand with no gravel, except over the underdrains which are spaced on 25-foot centers. The drains cross the bed to a ditch outside of and running longitudinal with the bed. Sludge is applied to splash plates at four points from 8-inch lines which are taken off a 12-inch header from the sludge pump.

Along the ends of each row of sludge drying beds there is a permanent 24-gage industrial track. When a bed is to be cleaned a spur track is laid through the center of the bed and cars are run in on this track.

Sludge disposal.—Some sludge, mostly that from the Imhoff-tank beds, is hauled from the beds by farmers, but the bulk of the digestion-tank sludge is taken to a drying plant located at the treatment plant.

Sludge drying plant.—Adjacent to the sludge drying beds there is situated a plant where air-dried sludge is heat dried. The sludge is carried in industrial cars, which are drawn by a 3-ton Plymouth locomotive, to the plant and dumped. This sludge ordinarily contains about 65 per cent moisture. From the dump he sludge is shoveled into a drag conveyor which carries it to a Renneberg tandard direct-heat dryer 6 feet in diameter and 40 feet long. When new this dryer was specified to dry 16 pounds of 70 per cent sludge to 4 pounds 10 per ent sludge per pound of fuel. From the dryer a conveyor carries the sludge to he screens, the screenings going by conveyor to the bagging hoppers and the ailing to a grinder and back to the screens.

Water supply.—The location of the treatment plant necessitates a private water supply. For general washing and flushing purposes the final plant effluent is pumped to a 100,000-gallon elevated steel tank. Water for drinking and use in the laboratories, etc., is obtained from a 6-inch well 150 feet deep and pumped to a 20,000-gallon steel tank slung under the 100,000-gallon wash-water ank.

Administration building.—This is an attractive concrete building with a basement and two stories. The basement contains a machine shop, storeroom, and eating plant. The first floor contains the general offices, lunch room, and oilets; and the second floor is given over to laboratories and a chemist's office.

IV. Canton, Ohio

Screens.—Sewage is discharged at the treatment plant from a rectangular 4-foot by 18-inch sewer into the screen chamber. This chamber is 22 feet long, 6 feet wide at the inlet, flaring to 11 feet wide 10 feet from the inlet and retaining this width for the remaining 12 feet. The bottom has a slope of one-half foot, giving depths of 4 feet and 4½ feet at the inlet and outlet, respectively, the inlet being level with the main sewer discharging into it.

At a point 6 feet 3 inches from the inlet an 18-inch wall divides the chamber into two flow channels. Each channel is, therefore, 4 feet 9 inches wide by 15 feet 9 inches long. Stop planks permit diverting the sewage into either or both of these channels. Each channel has a bar screen, one with a clear opening of 1 inch, and the other of three-fourths inch, both being inclined downstream at an angle of 30° to the horizontal. Allowing for the inset into grooves, the screens are 4 feet 11½ inches wide and 6 feet 8 inches long. They are cleaned by hand, the screenings being raked up onto a platform.

At the outlet of each channel is a measuring weir and the channels are connected to a chamber in which a float actuates a recording device on a 7-day chart. This recording apparatus is similar to that designed at the Lawrence, Mass., Experiment Station.

Grit chambers.—The screen chambers discharge into grit chambers, one for each screen. These are 40 feet long by 6 feet wide and are 6 feet 8 inches deep over all. Within the channels are hung two metal baffles or vanes, running longitudinally, which can be lowered or raised by lifting rods, thus increasing or decreasing the cross-section of the flow area of the channel. The grit drops through a slot between the vanes into a storage chamber. This design gives a cross-sectional appearance similar to an Imhoff tank, except that the baffles do not overlap. Its specific advantage is to maintain a constant velocity through the chamber by varying the flow section with the volume of flow. Up to the present no use has been made of this feature, due to the relatively constant volume of flow.

The bottoms of the chambers, in which are located drain pipes, slope both ways on a 5 per cent grade, but there are also flat false bottoms over the sloping bottoms. This arrangement is to facilitate drainage when the chamber is ready for cleaning.

Housing for screen and grit chambers.—Both the screen and grit chambers are housed in a substantial brick structure which is vented by a 28-inch iron stack 60 to 70 feet high. This stack is to serve also for a Morse incinerator, which was about to be installed to burn screenings. It was stated that the stack practically eliminated any odor nuisance arising from the screens and grit chambers.

Imhoff tanks.—Leaving the grit chambers the sewage flows into a flume 4 feet wide and 3 feet deep to the Imhoff tanks, the distance from the outlet of the grit chamber to the inlet of the nearest tank being 105 feet and the total length 211 feet.

There are 6 Imhoff tanks in all, but they are arranged in two groups of 3 tanks each. By changing the position of the stop planks or gates at the inlet and outlet ends the sewage may be made to pass through each group with the tanks in parallel or in series. It is also possible to reverse the order of the two outside tanks in each series. This effects the same results as reversing the direction of the flow.

Each tank is, over all, 24 feet wide by 89 feet long by 22 feet 1½ inches deep. The flow chamber is divided into two sections, each 10 feet wide, separated by a central gas vent, 3 feet clear width, running the entire length of the tank, except for sludge wells 2 feet by 3 feet over the center of each hopper. This vent is covered with notched 2-inch planks except where concrete walks are located. An 8-inch pipe connects the two channels near the inlet, thus equalizing head over the sludge chamber.

The inlet of each chamber is a free channel; the outlet, which becomes the inlet of the middle tank when tanks are operated in series, is over weirs, two weirs each 4 feet 8½ inches wide for each flow section of each tank. Two feet from the inlets and outlets are located scum boards, consisting of 2-inch planks laid in slots in the side of the tank, some extending down 1 foot 6 inches below the flow line.

The total depth of the flow chamber to the apex of the slots is 13 feet 4½ inches. The sides of the flow chamber are vertical for a distance of 7 feet 6 inches, where they slope inward at a 1 to 1.175 slope, or an angle of 49½°, to form the bottom. The slot at the bottom has a minimum perpendicular opening of 6 inches.

Over the center of each of the 6 hoppers there is a box in the gas vent 3 feet long, 2 feet wide, and 4½ to 6 feet deep, according to the position of the tank at which they are located, the 4½-foot box being at the outlet end and the 6-foot one at the inlet end.

The capacity of each flow chamber is 8,000 cubic feet, giving a total of 720,000 gallons for the 12 flow chambers of the tanks. This capacity was designed to give a three-hour detention for 6 m. g. d.

The sludge chamber has a total depth of 7 feet 7 inches from the overlap of the slot to the bottom of the hoppers. The hoppers, of which there are 6 for each tank, are 2 feet 9 inches deep, 14 feet square at the top and 18 inches square at the bottom. The slope of the bottom is therefore about 2.3 to 1. All hoppers are separated by walls through which a 2 by 2 foot opening is left, the bottom of which is 2 feet above the top of the hopper.

From each hopper an 8-inch cast-iron sludge pipe, with an 8 by 14 inch reducer as the inlet, rises to the sludge wells, already described, in the gas vents. Eight-inch, extra heavy, galvanized, wrought-iron pipes run longitudinally with the tank between these sludge wells, sloping 0.3 foot in 14 feet. The riser pipes from the hoppers are controlled by 8-inch plug valves, the minimum hydraulic head over the valve being 3 feet. In the last sludge well there is provided an 8-inch sluice gate to the flow channel whereby the wrought-iron sludge line can be flushed with the sewage in the tank.

To facilitate moving sludge from the hopper a three-fourths-inch lead water line is run alongside of and to the bottom of the sludge pipe, and, in addition, a 1½-inch lead line with one-eighth-inch spray holes at 18-inch centers run around the hopper. The 2-inch feeder line is laid on the top of the tank and is available for general use around the tanks. The sludge compartment of each tank has a capacity below the overlap of the slot of 7,614 cubic feet or about 45,700 cubic feet for the six tanks.

Contact beds.—The effluent from the Imhoff tanks is carried in an effluent channel 4 feet wide by 3 feet 3 inches deep to 16 contact beds. These beds all have an area of one-half acre, but are not all of the same shape. The eight nearest the Imhoff tanks are all 83 feet wide by 221 feet long. The remaining beds become wider and shorter so that the two beds farthest from the tanks are 143 feet wide by 111 feet long.

The filtering material consists of 12 inches of crushed slag, 1½ to 3 inch size, over the bottom around the collecting pipes, above which there is a 5-foot layer of 1 to 1½ inch crushed slag.

The main distributing flume passes through the center of the installation, eight beds on each side of it. The flume itself is 4 feet wide and about 2 feet deep covered with a 4-inch concrete slab. The depth varies slightly at different places as the bottom is given a drop of 0.2 foot.

From the flume, sewage is admitted to the beds through distributing chambers, entrance to which is controlled by hand operated stop plates 4 feet wide. The distributing chambers vary in width from 5 feet 4½ inches to 8 feet 3⅝ inches as the width of the bed increases from 83 feet to 143 feet.

The distributing ducts are 5 feet wide by 2 feet deep by 50 feet long. The bottom is concrete and contains 12 inches of screened clean one-half to 1 inch gravel. The outlet to the beds consists of 6 by 6 inch steel bar screens with one-fourth-inch clear openings set in the sides of the ducts below the gravel fill and on 1 foot 11¼ inch centers. At the termination of the main duct the sewage passes over a weir and enters an 18-inch vitrified-tile line laid with loose joints immediately under the surface. This pipe is reduced to a 12-inch line at a point one-quarter of the length of the distributing pipes from the end. The 12-inch line terminates in a 3-foot diameter manhole which extends 1½ feet below the pipe and is used to clean out deposits washed from the pipe. The general location of the distributing system is diagonally across the bed.

Around the main 5-foot distributing ducts are placed 18 inches of the one-half to 1 inch gravel, and around the pipe extension of the duct 4 feet of the same material.

Along one side of the duct is constructed a gravel washing shelf 2 feet 6 inches wide and 6 to 12 inches deep, with the bottom sloping toward the duct, and the whole shelf sloping toward the inlet end of the duct where is located a 4-inch cast-iron pipe to take the wash water to the sludge line from the tank.

In operation, the beds to be used are selected, and the sewage admitted by lifting the stop plates between the main distributing flume and the distributing duct. When the bed is full an alarm bell is rung which is the signal for dropping the stop plates.

The period of detention and discharge of the beds is automatically controlled by a 16-inch siphon, actuated by a timing device. The siphon is set in a concrete chamber 4½ feet by 4½ feet by 8 feet 4 inches deep, and the timing device in an adjacent connecting chamber 4½ by 2½ by 8 feet 4 inches deep.

Sewage is received at the siphon chamber through the collecting trough which runs longitudinally down the center of the bed. This trough is 3 feet wide with a depth varying from 7 inches at the far end to 16 inches at the siphon end. It is covered by loose-laid concrete slabs and the far end is vented. Feeding this main trough, 6-inch channel pipes with loose joints but plugged ends run to the sides of the beds. These lines are laid on 12 to 13 foot centers.

The siphons discharge into a main collecting gallery which is located directly under the distributing flume. It is 4 feet wide and about 6¼ feet deep.

Main outlet pipe.—The collecting gallery empties into a short 2 by 4 foot flume which ends in a manhole from which a 36-inch reinforced concrete pipe leads to a check valve manhole on the edge of the creek. The outlet from this manhole to the creek is through a 36-inch cast-iron pipe.

Sludge disposal—At the time of inspection there were six especially prepared sludge beds in operation. These beds were of similar construction except that three were covered with glass roofs of greenhouse construction. The beds are all 150 feet long by 24 feet wide, giving a total area of approximately one-half acre of which, as stated above, one-fourth acre is under glass.

The filtering material consists of one-half to 1-inch gravel 6 inches deep at the center, feathered out to zero at the sides, by the slope of the bottom. Above the gravel is a 15-inch layer of one-sixty-fourth to one-fourth inch sand. The bottom below the gravel is natural ground. It is claimed that the ground water during wet weather rises in the sand, interfering with drying. To remedy this it has been proposed that a concrete bottom be installed. It would appear however, that satisfactory results could be obtained by increasing the depth of the filtering material and installing more underdrains.

The sludge is applied by means of a gutter extending 80 feet over the bed. This gutter is 12 inches wide by 9 inches deep and constructed of 2-inch planks. The sludge flows by gravity from the tanks in a 12-inch cast-iron pipe to the center of the sludge bed installation. It is then diverted in a wooden trough 12 inches wide by 9 inches deep, and is discharged onto splash plates at the beginning and end of the trough over the bed. Temporary low plank partition walls have been installed across the beds dividing them in halves.

The underdrainage of the beds consists of a single 6-inch vitrified-tile line down the center of the bed. The bottom slopes both ways toward it 6 inches in 12 feet. The 6-inch drains all empty into an 8-inch cemented joint line to the creek.

For cleaning the beds a narrow gage, 24-inch railroad is run over the center of each bed. The base of the rails is 2½ feet above the top of the sand in the bed. With a car at this elevation the total throw from the beds to the top of the car s 5 to 6 feet, which is too high. The tracks all connect by turntables to a ladler track to the sludge dump.

As these six beds are not adequate to properly take care of the sludge, coniderable amounts have been lagooned in hollows and spread broadcast over the and. A sludge well was constructed from which a steam-duplex ball-valved pump draws suction. This installation has been used to pump to the lagoons and to the fields where the sludge is applied with a hose.

At the time of the inspection five new sludge beds were being prepared to which he sludge was to be pumped. These beds were being constructed by merely emoving the top soil, leveling and diking, the natural gravel soil being relied pon to give sufficient drainage without artificial assistance. These five new eds will have a total available area of a little less than 1 acre, or almost twice hat of the present beds.

All sludge dried on the beds or lagooned is hauled away by farmers and used on elds.

By-pass.—There is only one point at which it is possible to by-pass sewage ceived at the plant and that is between the Imhoff tanks and the contact beds. his by-pass is used during the winter months, the beds being idle during that eriod of the year.

Water supply.—Due to its location, city water is not available at the plant. ater is obtained from a 25-foot drilled well pumped by a standard lift pumping ngine made by the Standard Pump & Engine Co., of Akron, Ohio. The water is umped to a pressure tank for which there is an air compressor. A 4-horsepower s engine operates the pump.

Laboratory facilities.—There is a laboratory located at the plant but the facilies for work and equipment are inadequate for its proper functioning.

Recent improvements.—Since the survey, it has been reported by City Engier, W. E. Sarver that the following improvements have been made: (1) A boiler ouse constructed, and two boilers of 45 and 150 horsepower installed therein. (2) 16-ball-valve sludge pump, Wagner type, provided for pumping wet sludge to lds. (3) A three-fourths kilowatt Delco plant installed for lighting grounds and ildings. (4) A coal mine developed on property adjacent to the plant which d been purchased to settle damage claims.

V. COLUMBUS, OHIO

All sewage received at the treatment plants has been pumped, some of it twice. t the pumping stations it is passed through sand catchers and bar screens. hese have been described in detail in the body of this report under the description the Columbus survey.

The treatment plant, as it now stands, is an old plant rebuilt, the changes consisting principally in converting septic tanks into Imhoff tanks. There are now three sets of Imhoff tanks, the most northerly one nearest the inlet being called "battery A," the middle set "battery B," and the third or most southerly set "battery C."

Entrance chamber, influent and effluent channels.—The 48-inch force main to the plant enlarges into an oval-shaped covered entrance chamber located at the center of the north end of the "A" tanks. This chamber, at its inlet, is 5½ feet high by 10 feet wide, but narrows down in 13 feet to 5½ feet in diameter, and then divides into two 5½-foot conduits running in opposite directions along the north end of the tanks. These conduits can be controlled by stop gates. The branch running westerly is reduced at once to 24 inches in diameter and then to 20 and 15 inches after the second and third tank inlets have been passed. The easterly branch is continued with its original 5½-foot diameter to the northeast corner of the "A" tanks where it rises into an open channel, 6 feet wide by 4 feet 10 inches deep, which follows the east wall of the "A" tanks to the dividing wall between the "A" and "B" tanks, where it reduces to a 4½-foot width, and continues down the east side of the "B" tanks.

Where the reduction in width takes place, there is an opening in the side, 5 feet wide, controlled by stop planks through which sewage is fed to a 3-foot diameter influent conduit to the "A" or "B" tanks. This conduit is contained in the dividing wall between these two sets of tanks, and, as inlets to tanks are passed, it reduces in size to a final 15-inch diameter.

The 4½-foot influent channel along the east side of the "B" tanks reduces to 3½ feet at the dividing wall between the "B" tanks and "C" tanks, where there is a connection to the influent conduit to the "B" and "C" tanks. This conduit is a duplicate of that contained in the wall between the "A" and "B" tanks.

The 3½-foot influent channel continues paralleling the east wall of the "C" tanks, but separated from them by a tank effluent storage basin, to the southeast corner of this basin where it turns along the south end of this basin and of the "C" tanks, serving as either influent or effluent channel for these tanks.

The influent conduits described along the north end of the "A" tanks, between the "A" and "B" tanks and between the "B" and "C" tanks, feed, through 24-inch sluice gates, influent wells, which connect to channels 2 feet 10 inches to 3 feet wide by about 3 feet 5 inches to 4 feet 10 inches deep, the bottom sloping. The sewage passes into the tank from these channels or from the tanks into these channels over 8-foot weirs, two for each tank.

The arrangement at the south end of the "C" tanks is the same as for the other tanks except that there is no influent conduit or influent wells, only the channel serving either for influent or effluent depending upon the direction of flow in the tanks.

The main effluent channel follows the east side of the tank installation between the tanks and the main influent channel, passing over the influent conduits between the different sets of tanks. It is 4 feet 2 inches to 4 feet 10 inches deep, the bottom sloping, by 3 feet 6 inches to 6 feet 6 inches wide, the width increasing as more tanks feed into it. This channel discharges into the northeast corner of the tank effluent storage basin. The channel along the south end of the "C" tanks, when used for effluent, discharges directly into the main effluent channel to the filters.

Imhoff tanks.—In all there are 22 tanks of this type, all built inside of the septic tanks that composed the original installation. As the septic tanks were not the same in all respects the Imhoff tanks made from them differ. They are, therefore, described separately.

The "A" tanks, of which there are eight, constitute the most northerly set. These tanks are the double flow-chamber type, a central gas vent extending to within 5 to 9 feet of the ends of the tank. The over-all inside dimensions are: Length, 140 feet 8 inches from weir to weir, the last 5 feet on one end, however, not being full depth; width, 26 feet 7 inches; depth, 27 feet 1¼ inches. The crest of the weirs is 1 foot 5¼ inches below the top of the tank.

Each flow chamber is 11 feet 10½ inches wide by 15 feet 8 inches deep from the top of the tank to the apex of the slot. One side and the gas vents are veritcal for 7 feet 11½ inches below the top of the tank at which point they slope in on a 1 to 1.3 slope to an 8-inch clear opening slot with a 10-inch overlap. The other side is the wall of the old septic tank. It is vertical for 2 feet 8 inches. It then slopes in on a 1 to 2⅔ slope for a vertical distance of 8 feet 8 inches to the bottom of the old wall and is continued from here on a 1 to 1.3 slope to the slot.

The average sewage capacity of each of the two flow chambers from the crest of the weirs to the apex of the slot is 118,000 gallons. The capacities of the two flow chambers differ slightly due to the slope on the old end wall, but this difference is less than 1 per cent.

There are two scum boards beyond the weirs at both ends of the tank, one 3 feet 2 inches distant from each weir and the other two 19 feet 8 inches and 24 feet distant from the weirs at opposite ends of the tank. These extend down about 11 inches below the crest of the weirs. There are no other baffles.

The digestion chamber extends the full 140 feet 8 inches of the tank length. It is 14 feet 9 inches wide by 8 feet 10 inches deep from the slot overlap to the bottom of the hoppers. The space, 1 foot 7 inches deep, lying between the apex of the slot and the slot overlap is not included.

There are seven hoppers each 18 feet 7 inches long by 14 feet 9 inches wide on the top and 1 foot 6 inches square on the bottom. The depth is 4 feet 4 inches and the slope of the bottom 1.5 and 2 to 1.

Over the ridge between each hopper there is a dividing wall across the entire digestion chamber extending to the top of the gas vents. The two end sections and the three center sections are connected by three openings 3 feet wide by 2 feet high cut in these walls, but these openings are omitted in the walls between the second and third and the fifth and sixth sections.

The capacity of the digestion chamber is 13,500 cubic feet.

The central gas vent is 2 feet 6 inches wide, inside dimensions, and approximately 125 feet long, the two sides being brought together to form points at each end.

Each hopper has an 8-inch cast-iron sludge pipe rising vertically from the center of each to the top of the gas vent where it is capped. Four feet below the flow line an 8-inch horizontal line is taken off at a Y branch and run to a channel in the dividing wall between each set of two tanks. This channel is 2 feet wide and of varying depth, 7 to 11 feet, at different sections of the tank and for different tanks, the bottoms being on a minimum slope of 1.78 per cent and a maximum of 4.17 per cent. These sludge channels in the dividing wall between two tanks of the same type discharge into a collecting channel in the dividing wall between two types of tanks, which drain to a small sludge control chamber 4 feet 9 inches long by 8 feet wide, from which two sluice-gate controlled 12-inch cast-iron pipes lead to the channels along one end of the sludge beds.

The "B" tanks, of which there are eight, lie just south of the "A" tanks. With the exception of the weir to weir length, which is 126 feet 2 inches as against 140 feet 8 inches for the "A" tanks, the dimensions are almost identical, the maximum difference occuring in the width of the flow channel in two tanks out of the eight being only 9 inches, or about 6 per cent. These tanks are not therefore described in detail, reference being made to the description of the "A" tanks with notation of the difference in length, as stated above, which is taken up by the omission of one hopper. The arrangement of the influent wells is also slightly different, but not such as to affect operation.

Because of the shorter length, however, the capacity of the flow chamber and that of the digestion chamber is less for the "B" than the "A" tanks, they being, respectively, 108,000 gallons and 11,700 cubic feet.

The "C" tanks, of which there are six, lie south of the "B" tanks. They are almost identically the same as the "B" tanks, the main difference being in the weir to weir length of 117 feet 10 inches, or 18 inches more than the type "B" tanks. This 18 inches is distributed among the six hoppers, 3 inches to each. The majority of the flow chambers are 12 feet 10½ inches wide; 2 of the 12 are, however, 13 feet 7½ inches, a difference of 9 inches, or about 6 per cent.

The capacity of the flow chamber is about 109,000 gallons, and that of the digestion chamber 11,800 cubic feet.

Drains are provided for all influent wells. These connect to 18 by 18 inch tank drains, by which the tanks can be drawn down to the bottom of the flow chambers. The inlets to these drains are controlled by sluice gates, and they discharge into a large blow-off conduit to the river.

Tank effluent storage basin.—This basin lies on the east side of the "C" tanks, occupying a space equivalent to two Imhoff tanks. It is a large effluent well into which all the Imhoff tank effluents are received and passed on to the filters.

The over-all inside dimensions of this tank are: Length, 126 feet 6 inches; width, 56 feet 9 inches; depth, 5 feet 11½ inches, sloping to 8 feet 5½ inches.

The bottom consists of two rows of five hoppers, each 2 feet 6 inches deep and 28 feet by 25 feet to 28 feet 9 inches by 25 feet 4 inches on the top. From the center of these hoppers, 24-inch diameter openings outlet into effluent conduits under the center of each row of hoppers. These conduits increase in diameter from 2 feet 6 inches at the most northerly, or first hopper, to 4 feet at the fourth hopper. They retain this diameter to the south wall, which contains a 5-foot 6-inch main effluent conduit into which they discharge and which leads to the trickling filter control house.

Control house for trickling filters.—The 5-foot 6-inch effluent channel from the tank effluent storage basin passes under the filters to the control house. This is a two-story circular brick building built over the distributing and collecting wells. All control valves are on the first floor, the second being used for laboratory offices, toilets, etc.

The construction under the building consists of three concentric wells, 24 feet 3 to 9 inches deep. The tank effluent flows into the center well, which is 15 feet in diameter. As this fills the depth of sewage is shown on a float gage on the operating floor. When the proper level is reached, two 42 by 42 inch sluice gates are opened by hand on the operating floor. The bottom of this sluice gate is 9 feet 9 inches below an overflow in the wall of this well into the next outside well. There is thus an available storage above the outlet, which is practically filter surface level, of about 13,000 gallons.

The outlet sluice gates are left open till the gage shows the level at or near the bottom of the gates, when they are closed. These gates open into the second well, which is an annular ring 3 feet wide around the central influent well. This well is the distributing well, feeding 12 chambers through 24 by 36 inch sluice gates. These chambers are located in the effluent well and from them 30-inch main distributors lead to the trickling filters, one distributor for each unit. As, however, only eight filter units are installed, four distributors are idle. In operation the 24 by 36 inch gates from the distributing well to the main filter distributors are left open all the time, and control is maintained by the two 42 by 42 inch gates from the influent well to the distributing well.

The distributing well is also connected through six 24-inch sluice-gate-controlled pipes to the receiving chambers of the filter-collecting system, one chamber for each two filter units. These chambers discharge into the main effluent well.

The effluent well is an annular ring 4 feet wide around the distributing well. The distributing chambers, described above, are contained in the upper part of this well, leaving a space 8 feet 2 to 4 inches deep below them for the filter effluent. The main collecting drains from the filters discharge into chambers lying just outside this well, each chamber serving two filters, and these chambers outlet into the effluent well through 24 by 36 inch sluice gates. The effluent well discharges through a 66-inch conduit to the Scioto River.

Trickling filters.—There are eight trickling-filter units of 1¼ acres each. They are arranged in four equilateral triangles, radiating from the control house with a common apex at its center. Each triangle contains two filters, though there is no dividing wall between the two.

An individual unit is therefore a right triangle with a base 252 feet 7 inches and an altitude of 437 feet 5 inches, the control house occupying 19 feet at the apex.

The filtering material is crushed limestone. All filters have 10 inches of 3 to 4 inch stone at the bottom around the underdrains, and 4 feet 6 inches of 1½ to 3 or 1 to 3 inch stone above the 10-inch layer. One-half of the filters have the 1½ to 3 inch stone and the other half the 1 to 3 inch. These are the specified sizes, but much of the surface stone has disintegrated so that there is considerable small stone at or near the surface.

The main distributor, 30 inches in diameter, runs through the filtering material from the control house to the middle point of the base of the triangle containing the filter. Here is provided a connection to a 10-inch water main for flushing. Some few risers are taken directly from this main distributor, but the majority are on 5 and 6 inch laterals, which are taken off the main distributor on 13-foot 3⅜-inch centers and run parallel to the base of the filter. The laterals are terra-cotta pipe encased in concrete and lie about 3 feet 6 inches below the surface of the filter. The risers are 3-inch cast iron. Originally the nozzles, Columbus type, were screwed into the risers, but these are being replaced by the modified Columbus nozzle, which fits on the riser with a quarter turn. On the laterals themselves the nozzles are spaced on 15-foot 4-inch centers, staggered on alternate laterals to give a uniform spacing between all nozzles.

The main collectors start at the base of the filter, one-quarter distance from each end. These have 12-inch radius semicircular bottoms molded in the filter floor. One runs perpendicular to the base and the other parallel to the hypotenuse side of the filter, so that they meet at a manhole at the center of the filter. From this manhole an 18-inch radius drain leads to a manhole on the dividing line between two filters, about 53 feet from the control house. Here the corresponding drain from the other filter is also received and the two are continued to the control house in two parallel drains of the same size as those entering the manhole—that is, 18-inch semicircular bottom. The depth of all the drains varies because of the slope they maintain, the least depth at the start of the 12-inch drain being 18 inches and the maximum depth of the 18-inch drains where they enter the control house being 2 feet 3 inches. The drains are all covered by concrete slabs resting on the lateral underdrains. At the ends of the two 12-inch collectors water connections for flushing are provided.

The lateral collectors are 6-inch half-round tile of special construction laid over the entire bottom of the filter parallel to the base and on 8½-inch centers. These follow the slope of the bottoms, 1.62 per cent, in both directions from ridges to the main collectors.

Secondary sedimentation tanks.—Two secondary sedimentation tanks were included in the original installation. These are 11½ feet deep, but only 4½ feet is available for sewage. In plan they are 307 feet wide on the top, the sides sloping on a 1 to 3 slope to a bottom width of 247 feet, by 240 feet long at one side and 340 feet at the other. The inlet is through fifteen 21-inch vitrified pipes from a branch of the main effluent conduit to the river, and the outlet is over a weir at one corner. Only the bottom is concreted, the sides being natural ground. One of these basins has been materially modified. The changes are not given here, as difficulties in cleaning interfered with their normal operation to such an extent that they are no longer used, the filter effluent passing by them direct to the river.

Sludge beds.—There are 8 beds each 41 feet 6 inches wide by 195 to 315 feet long, 4 having the full length of 315 feet. The total area is slightly less than 2 acres. Each bed has two narrow-gage tracks on 10-foot 4½-inch centers, the base of the rails being laid flush with the surface of the bed.

The bottoms are laid on a 3 per cent slope from the center and two sides to two 3-inch tile drains laid on a 1 per cent slope in the channels. They discharge into two 8-inch drains which run across the beds one-quarter distance from each end and lead to the trickling filter collecting system.

The filtering material consists of 1 inch of sand, 2 inches of one-sixteenth to one-fourth inch stone, 2 inches of one-fourth to three-fourths inch and 3 to 7 inches of three-fourths to 2 inch stone.

The sludge is discharged onto splash plates at one end of the beds. In cleaning, cars are run onto the beds by a gasoline locomotive and hauled away when loaded to a dump on the inside of a levee along the Scioto River.

Laboratory facilities.—As already stated the laboratory is located on the second floor of the control house. The laboratory rooms are adequate, with ample equipment for all necessary work.

VI. Fitchburg, Mass.

Sewage treatment at Fitchburg, Mass., starts before the sewage reaches the treatment plant proper. The main interceptor carrying the bulk of the city's sewage discharges into grit chambers located somewhat over a mile from the plant.

Main grit chambers.—This installation originally consisted of one chamber 18 feet wide by 53 feet 9 inches long. The extreme width of 18 feet obtained for only about one-third of the length, the sides contracting toward the inlet and outlet. The bottom was nearly flat, except at the center, where there was a V trough with its bottom opening into a storage chamber 31 feet 6 inches long, 8 feet wide, and about 8 feet deep. This was cleaned through manholes, the supernatant liquor being pumped out by a 4-inch centrifugal pump.

Since installed, this chamber has been modified by a central partition wall dividing the large channel into two smaller ones. By inserting new end walls with gates the total length of the grit chambers proper are reduced, the constricted inlet and outlet channels being used in common by the two new chambers. By this arrangement one chamber can be cleaned while the other is in use.

Siphon.—From the grit chamber the sewage passes through a 48-inch sewer to the siphon entrance, a distance of about one-third of a mile. This siphon, inverted type, consists of a 30-inch cast-iron pipe approximately 1 mile long.

At the entrance chamber to the siphon is located an inclined bar screen with 1⅝-inch openings. This is cleaned by hand twice a day.

Low-level pump station.—The sewage system of South Fitchburg is too low to enter the inverted siphon by gravity. It is, therefore, collected at a point on the siphon about one-quarter mile from the treatment plant and pumped into the siphon. Before reaching the suction of the pumps, the sewage first passes through a bar screen with three-fourth-inch openings and then over a sump, which serves as a grit chamber.

The pumping equipment consists of two 4-inch American Well Works centrifugal pumps, shaft connected with flexible joint to two 10-horsepower Western Electric motors. They operate automatically by float-controlled starting and stopping devices, and pump against a head of about 65 feet. One pump is in operation practically continuously, the other being thrown into service only when the flow exceeds the capacity of the one in use.

Measuring device.—The 30-inch siphon discharges through a 30 by 15 inch integrating recording Venturi meter.

Imhoff tanks.—Primary sedimentation takes place in five Imhoff tanks. These receive the sewage direct from the Venturi meter and under the residual pressure from the inverted siphon. The inlet conduit is a 30-inch pipe with three 12-inch sluice-gate openings into the flow chamber of each tank. Both ends of the tank are identical, thus permitting the reversal of the direction of the flow in the tanks.

The outlet channels, one at each end of the tanks, are 3 feet 6 inches wide by 4 feet deep. They receive the sewage over outlet weirs extending over all except three 18-inch sections on each tank and discharge into the trickling filter dosing tanks.

At the time of inspection, June, 1920, four tanks were being used regularly as sedimentation tanks; the fifth was reserved largely for digestion of sludge from the secondary tanks, being, however, used as a primary tank if one of the other four had to be thrown out of service.

The tanks themselves are 90 feet long, 30 feet wide, with a total depth of 25 feet 11 inches. The flow line is about 1½ feet below the top of the tank, the exact distance being determined by the elevation of the adjustable outlet weirs.

The flow chamber proper is 26 feet wide by 90 feet long. The sides are vertical for a depth of 8 feet 6 inches where they start to slope inward on a 1 to 1½ slope to form the bottom and traps. The bottom of the chamber is of a saw-tooth shape, there being two inverted V partitions dividing the lower sections of the tank into three channels averaging 8 feet 8 inches wide at the top. The two inverted V partitions form with each other and with the two sloping sides three slots, one at the bottom of each channel. These slots have a slant opening of 6 inches, or a horizontal opening of a little over 6½ inches, and a trap overlap of 3 inches.

The bottom as well as the gas chimneys were constructed of rib metal reinforcing lath plastered with 2 inches of 1:2 concrete. This construction has not proved satisfactory. Several chimneys have failed and had to be replaced, the replacements being of plastered brick construction, and the bottom baffles have sprung between points of support, causing the slots to be uneven width.

Two gas vents, each 2 feet wide, run the entire length of the tank along the sides. In addition there are six chimney vents 2 feet wide by 9 feet long, venting the two inverted V's at three points directly over the lowest points of the sludge hoppers. The area of all vents is 17 per cent of the total area of the tank.

There are scum boards at each end extending down about 20 inches, but no baffles. Each flow chamber has an available capacity of about 24,000 cubic feet or 180,000 gallons.

The main walls of the tank are vertical for a distance of 18 feet 5 inches, where the bottom hoppers start. There are three square hoppers in each tank, each 30 by 30 feet in plan at the top, sloping down 7 feet 6 inches on a 2 to 1 slope to the bottom. There are no partitions or baffles between the hoppers.

Each hopper has an 8-inch cast-iron sludge outlet pipe rising vertically from directly under the center of one of the gas vents. This places it off center in transverse section, but over the center in the longitudinal section. Eight and a half feet above the tank it connects with a 10-inch horizontal riveted steel pipe through which it flows by gravity to the sludge beds. As the sludge beds are at a higher elevation than the surface of the sewage in the tank, it is necessary to lift the sludge to the beds. This is done by an air lift, the air being furnished through a 2-inch line entering the sludge pipe about 6 feet from its foot, by a Rix Gardner Air Compressor No. XD80, belt connected to a 10-horsepower Westinghouse motor. This installation is located in the basement of the administration and laboratory building.

No water connections have been provided to the hoppers. Below the overlap of the slots there is a total sludge digestion space of 13,000 cubic feet.

Siphon dosing tanks.—The effluent from the Imhoff tanks is discharged into the trickling filter dosing tanks. These tanks are arranged to receive and discharge alternately and are operated by air controlled Merritt automatic alternating 30-inch siphons.

The tanks in plan at the full-water level are each 32 feet 2¾ inches by 35 feet 3⅞ inches. Three sides of each tank are vertical construction while the fourth side combined with the bottom of the tank is irregular in shape, so designed as to create a uniform distribution of sewage over all portions of the filter. The total capacity of No. 1 tank is 53,765 gallons of which 47,161 gallons are discharged. The capacity of No. 2 tank is 57,814 gallons of which 50,391 gallons are discharged. The difference in capacity is due to the fact that the inlet weir of No. 2 tank is 0.47 of a foot higher than the inlet weir of No. 1 tank.

Trickling filter.—From the dosing tanks the sewage flows through a 36-inch cast-iron pipe to the trickling filter. This filter is rectangular with an effective area 405 by 223 feet or 2.1 acres.

The distributors run lengthwise with the filters spaced on 13-foot centers, and consist of 17 lines of 16-inch cast-iron pipe which are reduced to 12-inch over the extreme half of the filter. These distributors supported entirely by the filtering stone are laid at or just below the surface so that the nozzles are screwed directly into them and all risers thus eliminated. Each line is controlled by a separate 14-inch gate valve, making it possible to throw out of service any individual line without affecting the others. Inspection hatches are provided at each end of each line and at the reducers. There is a 6-inch blow-off valve at the extreme end of each line for flushing purposes.

There are 467 filter nozzles spaced every 15 feet on the distributors and staggered on alternate lines. The nozzle used is the modified Worcester type.

The drainage system on the filter bottom consists of troughs or channels having 11-inch top width and 3-inch depths. They are spaced 15 inches center to center, which gives 4-inch flat ridges between them. The channels slope from the central gallery (see below) toward the sides, at a grade of 6 inches in 106 feet, and discharge into two effluent channels, one of which is 21 and the other 30 inches, the latter being used also as a by-pass conduit. Both discharge into a 30-inch conduit to the secondary sedimentation tanks.

Above the channels, resting on the ridges, are laid concrete blocks, 17 inches long, 1⅛ inches thick, and 4 inches deep. The blocks on adjacent channels thus overlap 2 inches on each ridge. This construction gives about 33 per cent air space. Over the blocks is laid a layer of 3-inch cobblestones, and over these 10 feet of 1 to 2 inch broken trap and granite rock.

Through the longitudinal center of the filter is located a flushing gallery 4 feet wide and 6 feet high, inside dimensions, with a horseshoe-shaped arch roof. The bottom is 2 feet 5 inches below the filter bottom, and the top is covered by 6 feet 7 inches of filter stone. All the grooves of the filter bottom open into and slope away from this gallery. From it, therefore, ready inspection can be made of the drainage system. A 6-inch water connection to the gallery affords ample flushing facilities for cleaning the underdrains. Any stoppage in a drain is at once evidenced by back flow into the gallery.

Secondary sedimentation tanks.—A 30-inch concrete conduit carries the effluent from the filters to the secondary tanks. This conduit is provided with an overflow weir 25 feet long, with its crest 10 inches above the weirs on the secondary tanks and 8 inches below the top of these tanks. Thus any possible danger of flooding the tanks is eliminated.

The secondary sedimentation tank installation consists of four circular tanks of the Dortmund type. They have an inside diameter of 30 feet and a total depth of 24 feet, of which 14 feet 9 inches is vertical and 9 feet 3 inches is in the hopper bottom. The flow line or crest of the outlet weirs is 18 inches below the top of the tank.

The sewage is carried to the center of the tank in a 16-inch spiral riveted pipe and discharged into a vertical pipe made of ¼-inch boiler plate, 5 feet in diameter and 12 feet long. The point of discharge of this pipe is 12 feet 4 inches below the top of the tank or 10 feet 10 inches below the flow line. From there the sewage flows upward and outward radially to twenty-four 2-foot outlet weirs on the effluent collecting channel, which is located within and at the outer circumference of the tank. From this the effluent flows down a flight of concrete steps to the final effluent channel to the river.

The hopper, which underlies the entire tank, is 30 feet in diameter at the top and 2 feet 3 inches at the bottom. The sides have a slope of 1.4 to 1.

The sludge from these tanks is pumped into an Imhoff tank used as a digestion tank for this sludge. The outlet sludge pipes, which are 6-inch cast iron, run to a small pump house located close to the tanks. The pump, a 4-inch Epping-Carpenter centrifugal, shaft connected to a 15-horsepower Westinghouse motor, draws direct from any of the tank hoppers through a short suction into which all the sludge lines are connected but separated by gate valves.

The sewage inlet flume to the tanks acts as an inlet scum board. There are no other baffles of any nature in the tank.

The total capacity of each tank is 12,750 cubic feet. The capacity from the flow line to the bottom of the vertical inlet flume is 7,600 cubic feet or 57,000 gallons. This figure probably represents fairly closely the settling capacity of the tank. The remainder of the tank has 3,990 cubic feet, of which 2,280 cubic feet are in the hopper itself.

Sludge beds.—The original plant included 11 sludge beds, each 15 feet wide and 111 feet long, giving an area of about 0.42 acre. These are located adjacent to the Imhoff tanks but about 3 feet higher in elevation. The dividing walls consist of 2 by 12 inch plank. The bed itself consists of 6 to 8 inches of sand having an effective size of 0.15 mm. and a uniformity coefficient not exceeding 10. No underdrainage is provided because of the porous nature of the natural soil. Each bed has a narrow-gage track, with ties laid flush with the surface of the sand. As these beds have proved inadequate use is made of some low lying area near the plant for disposal of sludge by lagooning. This area is known as beds Nos. 12 and 13, and contains about 2 acres.

Administration building.—This building is of attractive brick construction consisting of a main floor and basement, which, however, has a ground level entrance at the rear. The main floor contains the office and a chemical and a bacteriological laboratory. Both are well equipped and in the hands of a competent laboratory man, who is in charge of the operation of the plant. The basement contains a pump room for the sludge air lift, a locker room with shower and toilet facilities for the men, and general storage space.

By-passes and overflows.—The main by-pass for the entire plant is the blow-off valve on the inverted siphon where it crosses under the river. Even after passing through the meter at the plant the sewage can be by-passed. The effluent from the Imhoff tanks can be sent around the filters, and there is an overflow in the siphon chamber to take care of excessive flows. The effluent channel from the filters to the secondary tanks has an overflow weir, by which it would be feasible to by-pass the secondary tanks.

VII. HOUSTON, TEX.

A. NORTH SIDE PLANT

Treatment of sewage tributary to the north side plant at Houston starts before it reaches the plant. The Willow Street pumping station, located in the center of the city, receives sewage from sewers high enough to discharge by gravity and also from three sections served by pumps. For one of these sections a 250-gallon Simplex ejector was being installed in August, 1920, to take the flow from a relatively small area. The other two areas are larger; one is served by two 4-inch Swaby centrifugal pumps, which operate intermittently, emptying a 15,000-gallon collection well. At this station the sewage is made to pass a screen with one-half inch clear openings as a protection for the pump. The third station has a 5-inch Buffalo centrifugal pump operating continuously, with a 500-gallon Simplex ejector to take peak loads. The pump at this station also is protected by a screen.

At the Willow Street pumping station the sewage is passed through screens and grit chambers and pumped by three 16-inch Gould centrifugal pumps to a 42-inch circular sewer to the treatment plant.

Screens.—Sewage enters the pumping station through a 36-inch gravity sewer which discharges into a manhole 6 by 8 by 10 feet deep. From this it can be by-passed direct to White Oaks Bayou or discharged through a short 3 by 3 foot connection into the screen chamber, which is 16 feet long, 6 feet wide, and 6¼ to 7 feet deep. The screen itself, made of one-half by 2½ inch bars with 1-inch clear openings, spans the entire width of 6 feet and is 10 feet 5¾ inches long, inclined downstream at an angle of about 18° to the horizontal. Cleaning is done by hand, the screenings being raked to a concrete platform at the top, from which they are carted to the city garbage incinerator near by and burned.

On one side of the screen there is an adjustable weir over which sewage is by-passed to an overflow chamber when the head on the screen is about 3 feet. This chamber is 10 feet long, 2 to 3 feet wide, and 3¼ sloping to 4¼ feet deep. It discharges through a 24-inch pipe to White Oak Bayou.

Grit chambers.—The screen chamber widens at its outlet into the grit chambers, of which there are two, each controlled by handwheel-operated sluice gates at both ends.

The chambers are 60 feet long by 6 feet wide. The bottom is constructed with three hoppers 9 inches deep, giving a total depth of 4 feet 9 inches at the top of the hoppers and 5 feet 6 inches at the bottom. From the bottom of each hopper an 8-inch pipe, controlled by a mud valve, connects through two 10 and a 12 inch pipe to White Oak Bayou. It is through these pipes that the chambers are cleaned, the deposits being flushed into the bayou.

The grit chambers discharge through a 36-inch pipe into the suction channels of the pumps by which the sewage is lifted to a 42-inch circular gravity sewer to the treatment plant.

Plant inlet.—The 42-inch sewer line discharges into an entrance chamber, from which it can be drawn into any of four 2½-foot wide by 4-foot deep channels, which lead to 4 aeration tanks; or it can be turned down and under the chamber through a 1½ by 4 foot orifice into a 48-inch by-pass, which discharges immediately into a 36-inch sewer to the Buffalo River. All these openings are controlled by handwheel-operated sluice gates.

Aeration tanks.—Sewage enters the continuous flow aeration tanks through an opening 4 feet deep and 10 feet wide, formed by simply cutting out the dividing wall between the influent channel and tank.

In all, there are four complete aeration units, consisting of an aeration and a reaeration tank, each unit the same as all others with the exception of the side upon which the reaeration tank is located. On either side of the center line of the installation there is a reaeration tank, then two aeration tanks, and finally another reaeration tank.

Each aeration tank is 280 feet long, 18 feet wide, and 10 feet 9 inches deep from the top of the tank to the top of the filtros plates at the bottom.

The bottom of the tank consists of ridges and channels across the tank. The ridges occur every 5 feet and, in section, are isosceles triangles with a base of 3 feet 10 inches and an altitude of 1 foot 9 inches. This leaves across the tank flat channels 1 foot 2 inches wide, with bottoms 3 inches below the base of the triangular ridges to receive the filtros plates.

There are 12 of these plates, each 12 by 12 by 1½ inches, in each channel. They were originally cemented with sulphur into cast-iron holders, 6 plates to a holder, to which the air pipes were connected. It was believed that the action of the sewage on the cast iron formed a sufficient amount of rust or iron hydrate to clog the plates badly. Whether the clogging was due to this cause or not, there was no question about their being clogged. All holders were, therefore, removed, the plates chiseled out, and subjected to an acid bath, after which they were replaced in the tank, but this time in concrete holders, and grouted in place.

At the inlet end of the tank an 8-inch cast-iron pipe leads to the sludge pumps and at the outlet a 12-inch line to drain the tank for cleaning, repairs, or when out of service for any length of time. A 6-inch channel down the center of the tank for its entire length, cutting all ridges, leads to this pipe and enables complete emptying of the tank. There are no baffles.

The outlet of the tank is an 18 by 48 inch sluice gate, located at one corner of the outlet end. This connects to a channel 4 feet 4 inches wide by 10 feet 9 inches deep with filtros plates in the hopper-shaped bottom of the channel. Adjacent tanks discharge into the same channel, and sewage is taken off from both sides to rows of sedimentation tanks.

Air distribution system.—Supported on the top of each tank and running down the center for the full length, is the main feeder pipe. This is a 12-inch line for 140 feet, 10-inch for 56 feet, 8-inch for 56 feet, and 6-inch for the remaining 28 feet. Spaced every 56 feet, beginning 28 feet from the inlet, a 6-inch and a 4-inch lateral are taken off the main feeder, these distribute air to three 4-inch lines which run the entire length of the tank and connect by 2-inch drops with the aerator plates. The 4-inch lateral from the main feed line supplies one of these 4-inch lines serving one row of plates in the main aeration tank, but the 6-inch lateral after supplying one 4-inch line for a row in the main aeration tank is extended by a 4-inch pipe to a second 4-inch line serving the plates in the sludge reaeration tank. From the end of the aeration tank a 4-inch line is carried down the center of the effluent channel and connected by drops to its plates to prevent sludge deposition before the sewage enters the secondary sedimentation tanks; and this 4-inch line is carried down the center of the sedimentation tank for sludge removal by air lift. A third 4-inch line is carried down that section of the reaeration tank adjacent to the secondary sedimentation tanks.

All the 2-inch drop lines to the filtros plates contain disks of canton flannel to filter the air.

Sedimentation tanks.—For each aeration unit 10 sedimentation tanks are provided. These are operated in parallel. The direction of flow in the sedimentation tanks is perpendicular to that in the aeration tanks.

The influent channel of these tanks is the effluent channel of the aeration tanks, already described. The inlet is through a submerged opening, 18 inches deep by 9 feet long, the bottom of which is 9 feet 2 inches from the top of the tank, or just at the top of the hopper channel containing the filtros plates of the influent channel. Control is exercised by flap gates operated from the top by a lever combination. These are, as a rule, set at an angle of about 45° and thus act as downward baffles. There are no other baffles in the tank.

The tanks themselves are 10 feet wide by 18 feet 10 inches long and 22 feet 10 inches deep. The two end walls are vertical for a distance of 9 feet 7 inches, at which point they slope on an approximate 1¾ to 1 slope, to a 3½ by 3½ foot bottom. The side walls have vertical depths of 17 feet 3 inches where they start sloping in on practically the same slope as the end walls to the bottom. The crest of the outlet weir is 1 foot 3 inches below the top of the tank.

In the center of each tank is suspended an 8-inch cast-iron sludge pipe. This reaches down to within a few inches of the bottom of the tank and terminates in a special flared mouthpiece. Near the top a horizontal 8-inch line to the reaerating channel is connected by a T. A four-pronged stirring device, operated by a rod through the center of the 8-inch sludge pipe serves to loosen the heavy sludge around the mouth of the pipe. Sludge is removed by an air lift, a 1-inch line entering the sludge pipe about 11 feet below the top of the tank. The sludge removal schedule is different at the two plants. At the south side plant it is customary to remove intermittently, the air being turned into the sludge pipe for a definite period and then shut off. A continuous flow of sludge is obtained by rotating tanks. At the north side plant a small hole is drilled through the valves on the air lines. The valve is kept closed at all times, but the air passes continuously through the drilled hole.

The outlet from the sedimentation tank is over two 3-foot weirs into channels 2 feet 4 inches wide by 4 feet 3 inches deep, one for each row of tanks. These all connect to an effluent-collecting chamber, discharge from which is also over weirs. It is at this point that the flow is measured by a gage recording the depth of flow over the weirs.

At the north side plant wooden troughs with 1-inch holes bored in the bottom have been set across the tanks. These are connected by 2-inch pipe siphons over the effluent weirs into the effluent channel. It was claimed that the velocity over the weirs without these siphons had been sufficient to cause currents which pulled up sludge and carried it into the effluent channel. The siphons corrected this by reducing the flow over the weirs. These troughs, however, have not been needed and have never been placed in the south side plant.

Sludge-reaeration tanks.—These tanks, one for each aeration tank, run the entire length of a complete unit of aeration and sedimentation tanks. They are in two sections. The first, a collecting channel, paralleling the sedimentation tanks, though separated from them by the effluent channel, is 104 feet 6 inches long by 3 feet 6 inches wide by 10 feet 9 inches deep. The bottom is hoppered and has one longitudinal row of filtros plates. This channel receives the sludge from the 8-inch sludge lines in the sedimentation tanks. Where the sedimentation tank and the aeration tank join, the sludge passes from this channel through an 18 by 48 inch sluice gate into the second section of the reaeration tank, which is 280 feet long, 9 feet wide, and 10 feet 9 inches deep. This section parallels and is adjacent to the aeration tank, and discharges into it at one side of the inlet end through an 18 by 48 inch submerged opening. Filtros plates are set in rows of 6 plates across the reaeration tank, the rows spaced 5 feet apart as in the aeration tank. The 6-inch channel for draining is also provided as in the aeration tank. The entire construction including bottom details is the same as for the aeration tanks, the only difference being that it is only half as wide.

An 8 inch sludge pipe to the sludge pumps is provided at the outlet end of the reaeration tank at the inlet end of the plant. In addition, the narrow section of the reaeration tank, is connected to the 12-inch line into which the aeration tanks are drained when it is desired to empty them. These connect to the main effluent pipe to Buffalo River.

Power house.—The power house is a brick building 72 feet long by 24 feet wide (inside dimensions). Adjoining it, with a common dividing wall, is the air screen chamber, 16 by 32 feet. The air screens consist of panels of 8-ounce duck backed by canton flannel. These panels, having a total area of about 700 square feet, are arranged on 8 diagonals, forming four V's across the 32-foot dimension, but occupying only 9 feet of the 16-foot dimension. The other 7 feet are taken up by baffle walls to two 20-inch diameter suctions for the blowers. Air is drawn in through 5 shuttered or louvered openings, 6 by 3 feet, in the outside walls.

Air is pumped by three Sturtevant No. 10 blowers, rated at 19.7 cubic feet of free air per revolution, 3,750 feet per minute at 265 revolutions. The blowers are gear connected to two 150-horsepower constant speed General Electric Co. motors and one 150-horsepower, 2 speed standard oil engine. All blowers connect to a 16-inch header which discharges through a 20-inch supply line. This divides into two 16-inch lines running along the inlet end of the aeration tanks. After two of the main feed lines over the aeration tanks have been taken off, the 16-inch header is reduced to 12 inches and supplies the main feed lines to the two outside aeration tanks. All four main feed lines are metered. Description has already been given covering the air system over the tanks.

The power house also contains a 6-inch special design Worthington volute centrifugal pump direct connected to a 10-horsepower General Electric Co. motor for pumping sludge.

Sludge disposal.—At the present time, and for the past two years excess sludge has been pumped to 3 lagoons, each of about 10,400 cubic yards capacity. The sludge is allowed to settle and the supernatant run back to the aeration tanks. At the time inspection was made, the middle of August, 1290, there was capacity left in these lagoons to take care of sludge for about 6 months longer. It was expected by that time to have the drying plant in operation.

This drying plant can best be described by taking up the various processes involved in the order in which they occur. From the sewage tanks the sludge is pumped to three elevated 50,000-gallon wooden tanks. Here it is allowed to settle and the supernatant drawn off. The settling period is limited by the fact that sludge quickly turns septic and in this condition is not suitable for pressing. The sludge in these tanks is supposed to be reduced from 99¼ to 98 per cent moisture.

From the settling tanks the sludge runs by gravity to two 500-gallon Simplex ejectors operated by two Gardner compressors driven by 20-horsepower motors. The ejectors discharge into two 120-plate Simplex presses, which, it is anticipated, will operate under 100 to 120 pounds pressure. The contract specification requires that these pressers will take 98 per cent moisture sludge and reduce it to 80 per cent, with a guaranteed output of 54,000 pounds of 80 per cent sludge per day. Each pressing requires about three hours.

The presses when cleaned drop the sludge into a chute to storage bin, where a conveyor picks it up and takes it to the drier. Conveyor trouble was the cause of the idleness of the plant at the time of inspection. The original conveyor installed was of the drag type. It was found, however, that the sledge stuck to the drags and returned to the sludge pit, instead of dropping into the drier. A screw conveyor to replace the one now in place had been ordered and was expected at any time.

The drier is a type A, direct-indirect Buckeye, 60 inches in diameter and 40 feet long, driven by a 25-horsepower motor. Heat is furnished by an oil-burning furnace. Gases are passed through a condensing chamber which outlets into a high stack. It was stated that very little odor was produced.

The installation contract requires that the drier handle 54,000 pounds of 80 per cent sludge per day, reducing it to a 10 per cent basis with a consumption of 1 pound of fuel, containing 13,500 B. t. u. per 10 pounds of water evaporated.

From the drier the sludge goes to an 8-inch mesh screen, the screenings being carried into the storage bin, and the tailings to a grinder and thence to the storage bin. All transfer of sludge is handled by conveyors.

Laboratory.—The laboratory is housed in a frame building. It is adequate in size and equipment for necessary work.

B. SOUTH SIDE PLANT

The bulk of the sewage treated at the south side plant is pumped at the south side pumping station. Here it is passed through a screen with 1-inch clear openings and lifted by two 12-inch No. 12 S., Gould centrifugal pumps to a 36-inch gravity line to the plant.

The south side plant is, in its main features and in most of its details, exactly the same as the north side plant, already described, the difference being that the south side plant is a two-unit plant, or half the size of the north side plant.

To avoid repetition descriptions will be made by reference to the north side plant, only points of difference being noted.

Plant inlet.—See north side plant, except two instead of four 2½-foot channels to tanks, and by-pass is 30-inch.

Aeration tanks.—Two units the same in every respect and dimension as described for north side plant.

Air distribution system.—See north side plant.

Tanks.—These tanks are slightly different from the corresponding ones at the north side plant. The end and side slopes start higher up and hence are steeper. The end walls are vertical for only 2 feet from the top, and the side walls 12 feet 10 inches, instead of 9 feet 7 inches, and 17 feet 3 inches, respectively, at the north side plant, giving slopes greater than 2½ to 1, instead of less than about 1¾ to 1.

Other dimensions, air and sludge lines, are the same at both plants. The south side plant, however, does not have the extra siphon outlets in addition to the weirs.

Reaeration tanks.—These are identical with those at the north side plant.

Power house.—In principle and general design this installation is the same as at the north side plant, though smaller to correspond to the size of the plant.

The power house itself is 36 by 24 feet and the air screening chamber is 16 by 16 feet with 4 panels. The panels are covered with muslin as against duck and canton flannel at the north side. The air intake to the blowers consists of one 16-inch header pipe to which are connected two No. 10 Sturtevant blowers driven by 150-horsepower General Electric motors, one variable and the other constant speed. These discharge into a 16-inch header which divides into two 12-inch lines for the tanks.

The sludge pump is the same as at the north side.

Because of the location of the plant it was necessary to provide a water supply. This is from a well pumped by a small motor-driven triplex pump.

Sludge disposal.—All sludge for the two years of operation has been pumped to a lagoon about 300 by 100 by 10 feet deep. This was about half full at time of inspection, and was counted upon for two years' more service. There is no drying plant, but it is possible that sludge may be taken from this plant to the drier at the north side plant if it is found that the commercial value of the dried sludge is sufficient to warrant the transportation expense.

Laboratory.—There is a combination tool house and administration building but no laboratory at this plant, that at the north side plant serving both installations.

VIII. LEXINGTON, KY.

Sewage is received at the treatment plant in 39-inch concrete sewer. This discharges into the entrance channel in which is located the screen.

Screen.—This is a bar screen made of ⅜-inch bars spaced 2 inches center to center, and inclined at an angle of 30° with the horizontal. In plan it is 3 feet wide by 8 feet long. Screenings are raked up by hand onto a concrete platform from which they are removed by a wheelbarrow and spread over land near by.

Grit chambers.—The sewage next enters grit chambers, of which there are three, all 3 feet wide, but two are 26 feet 6 inches, while the third is 30 feet 9 inches long. Their effective depth is 4 feet 9 inches. Below this depth there is a channel, 12 inches deep at the inlet increased to 15 inches deep at the outlet in which is laid a 6-inch vitrified drain tile and the channel filled with one-eighth to three-fourths inch graded broken stone. These tile are extended by 4-inch cast-iron pipes to a 4-inch vertical Morris centrifugal pump, shaft connected to a 2-horsepower General Electric Co. motor. The pump and motor are located in the laboratory and administration building and are used to pump out the grit chambers before cleaning.

Inverted siphon.—This siphon carries the sewage from the grit chambers under the Louisville & Nashville Railroad tracks to the influent channel of the Imhoff tanks. The siphon entrance chamber is 12 feet 6 inches long with an inlet width of 3 feet, which increases or flares to 8 feet within the first 5 feet, giving an 8-foot width for the remaining 7 feet 6 inches. There are two outlets or siphon pipes. The first is 24 inches, reducing to 18, and controlled by a 24-inch circular sluice gate. The second is an 18-inch pipe controlled by an 18-inch special Pacific flush tank siphon, the outlet arm of which is in the form of a T, one opening extending up above the discharge point of the siphon. The 24-inch straight opening is used regularly. When the flow becomes too great to be entirely taken care of by this pipe the siphon operates to take the excess, and the riser from the outlet arm of the siphon constitutes an overflow in case the siphon fails to function properly. The two 18-inch pipes pass under the railroad tracks and discharge through risers into an elevated tank inlet conduit.

Imhoff tank inlet conduit.—The conduit from the siphon to the Imhoff tanks is 410 feet long, 3 feet wide by 4 feet deep. At one point an angle of 68½° is turned on the arc. For the greater part of the way this conduit is elevated 5 to 6 feet above the ground, though it is planned eventually to fill under it. The installation is complete to serve 8 tanks but only the four farthest from the siphon have been built. The others are to be added as needed.

Imhoff tanks.—The four Imhoff tanks are of the single chamber, reversible, horizontal flow type. They are 68 feet long by 33 feet wide and of a total depth of 28 feet 8 inches. Sewage enters and leaves over two 12-foot weirs, the crests of which are 2 feet below the top of the tank. There are two gas vents, one over each of two hoppers, 6 feet wide by 13 feet long.

The flow chamber has a total depth of 14 feet below the flow line to the apex of the slot. Of this, 5 feet 10 inches is vertical wall above the sloping baffles forming the bottom. These have a slope of 1¼ to 1. The slots are formed by sloping in all four walls of the tank and sloping out the four walls of each gas vent. This method of construction gives eight distinct slots, four longitudinal with the tanks formed by the four side walls of the two gas vents with the two side walls of the tank; and four across the tank at right angles to the flow, two of which are formed by two end walls of the tank with the two outside end walls of the two gas vents and two formed by the two inside end walls of the two gas vents with a vertical partition wall between the two hoppers terminating in a wedge. In all slots the horizontal opening is 9 inches and trap overlaps 10½ inches.

Scumboards are located 18 inches from the inlet and outlet. In addition there are two baffles 21 feet 6 inches from the inlet and outlet. Both the baffle and scumboards extend from the top of the tank down about 3 feet below the surface of the sewage. They consist of 2-inch cypress boards 10 inches wide, slipped in grooves in the walls of the tank.

Below the slots the sludge or digestion chamber is 11 feet 1 inch deep, of which 4 feet 6 inches are in the hopper bottoms which are 27 by 20 feet wide at the top, sloping to 18 by 18 inches at the bottom. The slope of the bottoms, transverse and longitudinal are, therefore, about 2 to 1 and 3 to 1, respectively.

The settling capacity, exclusive of the gas vents, from the flow line to the apexes of the slots is 20,600 cubic feet or 154,500 gallons.

Each hopper has an 8-inch cast-iron sludge outlet pipe which rises vertically from a point 12 inches above the bottom to the top of the tank, but at a point 4 feet 6 inches below the flow line is connected by a T to a horizontal 8-inch line which runs across the tank and terminates in a small sludge well between two adjacent tanks. From this a 16-inch sludge line goes to the sludge bed. Water lines have been installed around the top of the hoppers with a connection directly under the bottom of the outlet sludge pipe.

The sludge storage capacity below the overlap of the slot is 8,700 cubic feet.

Siphon chambers or dosing tanks.—There are two dosing tanks for the trickling filters, each serving two of the filter units. The tanks are divided into two sections emptied by a 24-inch, Pacific flush tank, alternating, twin, lock-controlled siphon. The siphons are located in chambers 28 feet long by 10 feet 7 inches wide with sloping bottoms so that the depth varies from 4 feet 4 inches to 12 feet 4 inches, the last 5 feet 6 inches being level at the 12 foot 4 inch depth.

The total capacity of each chamber, including the siphon bell, is 2,575 cubic feet; of this, 1,465 cubic feet or about 11,000 gallons is available and constitutes the dose discharged on the filter at each discharge.

Trickling filters.—The filters consist of four units of trickling filters of one-half acre each, arranged in two sets of two each. The filters are all 238 feet 6 inches long, but the two outside filters are 92 feet 6 inches wide, while the two inside filters lying adjacent to each other are 91 feet 3 inches wide.

The floors slope 6 inches in the width of the filters equivalent to a little over a 0.5 per cent grade. Six-inch half tile drains with open joints are laid on 10½-inch centers. These pass through the wall of the filters and discharge directly into two secondary sedimentation tanks located between and each serving two filters. The ends are open and can be easily flushed by a hose for which connections are available.

The filtering material consists of 3½ feet of native limestone surfaced with 2½ feet of Georgia granite. The specifications call for 2 to 2½ inch stone, but there is some smaller than 2 inches so that as the filters stand the size is 1 to 2½ inch. Around the open points of the half tiles of the underdrains larger stone were placed by hand. The use of the granite for the top 2½ feet was due to a serious doubt as to the wearing qualities of the native limestone. Due to transportation difficulties, however, it was impossible to secure quite enough granite and a small section of the filter was filled to the top with the native limestone. At the time of the survey, August, 1920, after three years of operation there appeared to be very little if any disintegration.

Sewage is discharged from the dosing tanks through a 30-inch pipe, which, at the filter, is divided into two 20-inch lines which are gradually reduced to 12-inch at the lower end of the filters. All lateral distributors are 6 inches, laid on 13-foot centers and supported by the filter stone about 6 inches below the surface. Into these are set circular Taylor nozzles on 15-foot centers staggered on alternate lines, thus giving a uniform spacing of 15 feet over the filter. The hydrostatic discharge head on the nozzle varies from a maximum of 9.75 to a minimum of 2 feet.

Secondary sedimentation tanks.—Each set of two filters discharges into a secondary or final sedimentation tank. These tanks are located between the filters they serve, and form the bottom of the uncovered central pipe gallery. They have a total length of 221 feet 4 inches and a total inside width of 12 feet. This width is divided into three sections: Two channels of 1 foot each into which the filters discharge, and the third, a central channel of 9 feet into which, at the inlet end, the two side channels discharge. The sewerage is thus carried back through the 1-foot channels to the 9-foot channel and then through the 9-foot channel the complete length of the tank. The bottoms of the side channels are flat, but that of the central channel consists of 16 hoppers, each 9 feet by 13 feet 10 inches in plan at the top and 18 inches by 18 inches at the bottom. Each hopper has a 4-inch valve-controlled sludge outlet connected to the 4-inch suction line of a 6-inch Morris vertical centrifugal pump, shaft connected to a 10-horsepower General Electric Co. motor. This pump discharges into the inlet channel of the Imhoff tanks. It is operated about every six weeks.

Final effluent channel.—From the secondary tanks the sewage flows over a weir into a 30-inch cast-iron effluent pipe, which discharges into Town Branch through a 36 by 36 inch open concrete conduit.

Sludge beds.—There are two sludge bed units, each 105 feet long by 83 feet wide. Each unit is divided longitudinally by three 9-inch partition walls into four beds, 105 feet long by 20 feet 3 inches wide. One bed of each unit is again subdivided by removable wooden partitions into five sections 21 feet by 20 feet 3 inches. The two units lie adjacent to each other with a sludge channel between them 12 inches wide, 18 inches deep, with semicircular bottom. A similar channel lies also on the end of each bed nearest the tanks. They are laid on a 2 per cent grade. Openings with slide gates or stop planks permit the sludge to be put on any desired bed. Below each opening on the bed there is a concrete splatter plate 5 feet long and 3 feet wide flaring to 7 feet. Tracks, 24-inch gage, run down the center for the length of the bed and connect by turntables to a main track which runs up on a trestle over the sludge dump.

The bottom of each bed slopes 2 inches from both sides to the center, a distance of about 10 feet, where an 8-inch open-joint tile drain is laid in a channel. These empty into an 8-inch main drain which runs to the underdrainage system of the trickling filters. The depth of the material in the bed averages about 1 foot, and consists of a one-fourth-inch surface of sand, under this 2 inches of one-sixteenth to one-fourth inch stone, then 4 inches of one-fourth to three-fourths inch stone and finally 5 to 6 inches of 1 to 2½ inch stone.

Laboratory and administration building.—Though not equipped for laboratory work, the plant has a brick building 40 by 26 feet overall, in which a room 24 by 26 feet has been set aside for a laboratory. The stationary fixtures, hood, benches, sinks, and worktables are already in place. The remainder of the building is taken up with a toilet, shower bath, the inlet chamber of the inverted siphon, already discussed, and the pumping equipment for draining the grit chambers.

Overflows and by-passes.—The plant is so arranged that any or every device can be cut out of service. Just preceding the bar screen there is an overflow leading around the screen and grit chambers to the inverted siphon chamber. This overflow is available for heavy storm flows and is a safeguard against clogged screens. In addition to this overflow there is a by-pass around the grit chambers for screened sewage to the inverted siphon chamber. At the outlet of the inverted siphon a valve-controlled blow-off makes possible the discharge of the sewage at this point direct to Town Branch through an 18-inch cast-iron pipe. After leaving the tanks there is, on the line to the dosing tanks and just before entering them, a 24-inch valve-controlled by-pass pipe which leads to a 36-inch drain. This drain was installed to intercept and carry underground to Town Branch a former surface run or brook. The filters can be cut out by opening a valve at the end of the main distributors, allowing them to discharge just ahead of the outlet weir of the secondary tank, or the filters can be operated alone without the secondary tanks by empting the two narrow 1-foot channels into the final effluent conduit at a point just beyond the weir of the 9-foot channel into the final effluent conduit.

IX. Reading, Pa.

Sewage treatment at Reading is divided into three steps at three different places. The sewage is first screened and grit removed at a pumping station in the southwest corner of the city. From this point it is pumped over a mile south to a large septic tank, from which it flows over a half-mile to trickling filters and secondary sedimentation tanks on Fritz's Island, the effluent finally entering the Schuylkill River.

Screens and grit chambers.—Sewage is received at the pumping station in a 54-inch brick sewer from which 54-inch leaders are taken to the two screen chambers. These chambers are circular, 20 feet in diameter and 19 feet deep, with flat bottoms, the sewage entering with the invert of the sewer 8 feet above the bottom. One foot below the invert of the sewer is the screen, supported by an iron grid, consisting of cast-iron plates with half-inch holes on 2-inch centers, laid in sections to cover the entire diameter of the pit. The sewage entering these chambers submerges the screens, during periods of operation, to a depth of 3 to 8 feet, depending on the extent of clogging. The sewage passes through the screens to a pit 7 feet deep and from it to the suction of the pumps.

This suction is located about 18 inches above the bottom of the screen chambers, the depth below the suction being available for retaining grit. It is obvious, as has been demonstrated, that this grit storage space is quickly filled, and that the grit is then washed onto the pump as rapidly as it is deposited.

The screens are cleaned by hand. One screen is thrown out of operation and the sewage pumped down below the screen plate. The exposed plate is then cleaned with a flat-edged scraper, the screenings being collected into a pile and shoveled into a bucket, which is lifted to the top of the well, dumped into steel carts, and pressed. The steel carts have perforated bottoms, solid sides, and open fronts. A wooden cover is placed over the screenings and pressed down by a jackscrew operated by a handwheel. The pressed screenings are burned in an incinerator. For the most part, there is a fixed schedule of cleaning from 8 a. m. to 9 p. m. During the night the screens are cleaned when needed.

In cleaning the grit chambers, sections of the screen are removed, and the deposits shoveled into a large container which is raised and lowered by a motor-driven windlass, mounted on an I-beam traveler. By this arrangement the container can be conveniently placed in the pit, and, when full, lifted and carried outside the building where it is dumped into a wagon.

Pumping equipment.—This consists of a R. D. Wood 12-inch, horizontal, centrifugal pump, 6 m. g. d. capacity, direct-connected to a 100-horsepower Westinghouse motor; and a R. D. Wood 15-inch, horizontal, centrifugal pump, 8 m. g. d. capacity, direct-connected to a 150-horsepower Westinghouse motor.

These are controlled both by hand and by a Cutler-Hammer automatic float device. The two pumps are never operated together.

From the pumps, a force main, 6,600 feet long and 20 inches in diameter, except for a few hundred feet near the pumping station, leads to the septic tank. On this line, at the pumping station, the sewage passes through an integrating direct-recording Venturi meter.

Septic tank.—This tank is 253 feet long by 51 feet 8 inches wide by 17 feet 4 inches deep. All sides are vertical and the bottom is flat with, however, a slight slope to facilitate removing sludge. The tank as a whole stands above ground. The bottom is divided into five compartments by transverse baffle walls, 4 feet high. These compartments are connected by openings 1 foot wide, cut at both ends of the baffle walls. Crossbeams 1 foot high divide each compartment into four bays or smaller sections. A 6-inch sludge outlet is provided for each of the five compartments.

There are no surface baffles, but an outlet scum board extending 3 to 4 inches below the surface of the sewage is provided. This scum board normally stands near the outlet, but it is movable, and is used to pull scum toward the inlet end of the tank where it is shoveled off into a chute to a large drying area. This is done about twice a week.

The 20-inch force main passes through the bottom of the tank at the inlet end and rises vertically for 11 feet where it discharges the sewage into a horizontal 14-inch riveted steel header, about 45½ feet long across the tank. Twelve 5-inch holes, on 3½-foot centers, are cut in the header 45° below the horizontal.

The outlet is over a timber weir extending across the entire width of the tank with its crest 1.15 feet below the top of the tank. The effluent enters a trough 2 feet deep the full width of the tank and discharges through a 24-inch vertical pipe to a 30-inch line to the filters.

An overflow weir, 32 feet 3 inches long, is provided in one side of the tank near the outlet end. Its crest is about 5½ inches above the crest of the outlet weir and about 8 inches below the top of the tank. The sewage passing over this weir spills onto an apron projecting 10 inches from the side of the tank and falls into a channel leading to Angelica Creek just above its entrance into the Schuylkill River.

It was stated that this weir overflows every Monday for about four hours and occasionally for about a half hour during the rest of the week.

The total volume of the tank is 226,000 cubic feet. With the flow line 1 foot below the top, the available volume is 213,000 cubic feet. Considering also the 4-foot depth below the bottom baffles as dead space for sludge storage, the available sewage capacity becomes 161,000 cubic feet or 1,200,000 gallons, and 52,000 cubic feet for sludge.

Trickling filters.—From the septic tank the sewage flows in a 30-inch pressure main under Angelica Creek and Mifflins Arm of the Schuylkill River to the filter beds on Fritz's Island. The pressure line discharges at the center of the bottom of a weir tank 10 feet in diameter by 12 feet deep. The bottom of the tank is about 10 feet above the ground and 10 feet below the surface of the sewage in the septic tank. Inside the tank three walls, chords of the circle of the tank, divide the tank into a central triangular entrance chamber and three outside segmental-shaped outlet chambers. The dividing walls are solid to a height of 3 feet above the tank bottom, and grooves extend up another 4 feet, so that 2-inch planks can be set in them to obtain separation of the flow into the three outside chambers by merely adjusting the elevation of the top planks which serve as weirs.

The three outside chambers discharge through two 24-inch and one 30-inch vitrified pipe to the siphon tanks of the filters. The two chambers, with the

24-inch outlets, feed only one filter each, but the third, with the 30-inch outlet, feeds two filters.

While at the time of inspection there were 4 dosing tanks of two types, 1 controlled by butterfly valves operated by floats and 3 by siphons, only the siphon type is described here, as it was stated that the butterfly valve tank was unsatisfactory and would be replaced by a siphon tank of the same design as the other three before the summer was over.

The siphon tanks are hopper-shaped with three sloping and one vertical side. One of the sloping sides overhangs the filter bed and has openings cut in it near the top so that any flooding will be onto the beds. The tanks are 7½ feet deep and have a capacity of about 12,000 gallons. Sewage enters through a 24-inch pipe in the bottom and leaves through a 24-inch siphon.

The four filter units were installed at different times between 1907 and 1915, and, though built on the same general lines, they differ in details of design. They are all 1 acre in area. The details can be most satisfactorily given by considering each filter separately.

Filter No. 1.—This filter was constructed in 1911, being the third one built at the plant. The floor is of concrete, sloping both ways toward one central drain. Laterals of 6-inch half-round tile on 11-inch centers run from this drain to the two sides of the filters. Around and over the laterals to a depth of about 6 inches are laid large pieces of slag averaging 6 inches in diameter. Above this is the layer of regular filtering media of open-hearth furnace slag 4½ feet deep. The filtering media was specified 1½ to 4 inches in diameter, but either the screening was carelessly done or the slag had disintegrated, as much material under 1½ inches was observed on inspection.

The distribution system from the 24-inch siphon consists of four main 12-inch terra-cotta feed lines encased in concrete. These four lines extend one-fourth, one-half, three-fourths, and the full length of the filters, supplying the first, second, third, and fourth quarter, respectively. All are controlled by separate valves. From the main feed lines, 6-inch terra-cotta laterals, encased in concrete, are run on the bottom of the filter at 14-foot centers. The risers, 4-inch cast-iron pipes, are spaced 13 feet 8 inches on the laterals. Iron plates are bolted to the tops of the risers, and the 218 nozzles, Reading type, are screwed into these plates. As the nozzles are staggered on alternate feed lines, the diagonal, distance between nozzles is about 15 feet 4 inches as against 13 feet 8 inches between two nozzles on the same lateral. As the original design called for 6 feet of filtering material and only 4½ feet was placed, the risers project about a foot to 18 inches above the beds.

Filter No. 2.—This filter built in 1909 was the second one to be installed. The concrete floor slopes from a central gallery toward the two sides, dropping 9 inches in about 100 feet. On this floor, following the slope, are the lateral collecting drains consisting of 6-inch half tile laid with a 1-inch space between two adjacent lines and with joints staggered. These discharge into the two main drains, one on each side of the filter, each 2 feet deep with circular invert molded into the bottom of the filter. These drains have a slope of about 5 per cent. They discharge into a 24-inch pipe running across the lower end of the filter and emptying into the secondary sedimentation tank.

The main feed line is a 24-inch pipe running down the center of the filter under the gallery, which is about 4 feet wide by 6½ feet high. The lateral distributors, 6-inch tile pipe, are taken off the main feed line at 12-foot 4-inch centers, each line being controlled by a 6-inch gate valve located in the filter gallery. The risers, 3-inch cast-iron pipe, are taken off the lateral distributors every 12½ feet by 6 by 6 by 3 inch virtified tees, the connection being surrounded by a block of concrete. Risers on adjacent laterals are staggered. The top of the riser is flanged, and a cap into which the nozzles, Weand type, are screwed, is bolted to this flange. This filter has 254 nozzles spaced 12½ feet on the same lateral, but with a diagonal distance between nozzles on adjacent laterals of about 13 feet 7 inches.

The filtering material consists of local feldspar, of 6 feet 3 inches to 7 feet deep at the center and sides, respectively, of specified 1 to 2½ inch size. As in the case of filter No. 1, it was observed that there was considerable material less than 1 inch. This stone breaks into flat pieces with parallel cleavage planes.

Filter No. 3.—This filter, constructed in 1915, was the last one built. It is the same design as filter No. 1, except for the filtering material which consists of 5 feet of 3-inch slag. This material was carefully screened and is all of a very uniform size.

Filter No. 4.—This filter, constructed in 1907, was the first one installed. The bottom of the bed, which is of concrete, slopes 1 foot from both ends of the bed to a central trough across the bed. This trough is 2 feet wide and 4 inches deep at the sides sloping to 12 inches deep at the center. At right angles to this trough 6-inch half-tile laterals are run on 10-inch centers up the sloping bottom to the ends of the filter. Concrete slabs 36 inches square, supported by sills over the ends of the half-tile laterals, cover the central trough. Around and over the lateral drains are laid large pieces of slag 5 to 6 inches in diameter. The 30-inch effluent pipe runs from the center of the collecting trough under the filter floor to the secondary sedimentation tank.

The filtering material consists of specified 1½ to 4 inch slag 5 feet deep. Either the slag has disintegrated or the screening was poorly done, for there is considerable material less than 1½-inch size most of which is too small for a filter of this type.

The distribution system consists of a 30-inch tile-pipe feed line across 96 feet of the inlet end, but outside the bed. From one end a 30-inch tile pipe and from the other end a 28-inch square conduit extends to the center of the filter and connects with a 24-inch header across the entire width of the filter. This header is divided into four sections by valves on either side of the two influent lines, each section serving one-quarter of the filter. From the 24-inch header are taken 8-inch lateral distributors on 13-foot 9-inch centers. These are embedded in concrete. The 4-inch risers fit into tees on the 8-inch lines, and are set on 14-foot 2-inch centers. As the risers are staggered, there is a diagonal distance of about 15 feet 5 inches between risers on alternate lines. The 218 nozzles, Weand type, screw into plates bolted to the top of the risers. As the risers were built for a 6-foot depth of filtering material instead of the 5 feet actually placed, they project about a foot above the surface of the filter.

Secondary sedimentation tanks.—Each filter has a secondary sedimentation tank constructed at the same time as the filter. While similar in general plan, the details are sufficiently different to warrant individual description.

Tank for filters Nos. 1 and 3.—In plan this tank is about 96 by 100 feet, with the sides vertical. It is 3 feet deep at the inlet end, sloping to 4½ feet at the outlet end, where there is a sump to which sludge is pushed when cleaning the tank, and from which it is pumped by a small portable gasoline engine driven pump. There is provided a 6-inch drain valve to take off the supernatant liquor over the sludge before its removal.

Sewage enters through four 12-inch pipes from the 24-inch line from the filter. The discharge is over a weir into a concrete trough, from which a 24-inch pipe leads to the river. There are no baffles or scumboards. The available capacity is about 300,000 gallons.

Tank for filter No. 2.—This tank is approximately 110 by 95½ feet in plan and 3½ to 4 feet deep at the inlet end, sloping to 5 feet at the outlet. The side walls are on a 1 to 1 slope. Arrangements for cleaning are the same as described for the tank for filter No. 1.

Sewage enters through eight valved 12-inch pipes tapping the 24-inch effluent pipe from the filter which runs parallel with the inlet end of the tank. The outlet arrangement is the same as the tank for filter No. 1. There are no baffles or scumboards. The capacity is about 300,000 gallons.

Tank for filter No. 4.—This tank is the same as that for filter No. 2, except that the inlet consists of four openings from the effluent pipe of the filter.

Sludge beds.—There are no specially prepared sludge beds. The sludge and scum from the septic tank are run onto a large low-lying sandy area which is cleaned once a year. Several doses are given, one on top of the other, but as the area is fairly large it has been able to handle all sludge so far.

The sludge from the secondary sedimentation tanks is also applied to land near the tanks. This land was originally cleaned of vegetation, but at the time of inspection, July, 1920, it was entirely covered with a rank growth of weeds. Because of the amount of land available, however, it has been possible to handle all the sludge by this method, which might best be described as a cross between lagooning and bed drying.

Disinfection.—When work is being done on the tanks or filters or the treatment devices thrown out for any reason, and when the sewage flow exceeds the capacity of the pipe from the tank to the filters, the sewage is pumped direct to the canal at the pumping station. At such times calcium hypochlorite is applied to the sewage. The dosing apparatus stands in the open on the bank of the canal and consists of two 50-gallon barrels, one of which is free and the other connected by a feed line to the discharge pipe into the canal. Fifty pounds of the hypochlorite are mixed in the free barrel and dumped into the stationary one, from which it is fed through a small hand-controlled valve to the sewage at a nominal rate of 150 pounds of hypochlorite per million gallons, or about 4½ to 6 parts per million, but with no retention or contact period for the reaction. It is very doubtful whether this treatment, as used here, is of much value.

By-passes.—There are many points at which it is possible to by-pass sewage direct to the river. At the pumping station the sewage can be discharged direct to the river through the canal. It is possible to by-pass the septic tank entirely or to turn the effluent from the tank into the river, by-passing the filters. The filter effluent can in turn be carried around the secondary sedimentation tank. The overflow at the septic tank has already been mentioned.

Laboratory.—A small laboratory building is provided at the filter plant installation on Fritz's Island, but all analytical work is done in the board of health laboratory at the city hall to which the samples are taken, the chemist seldom visiting the plant itself.

X. ROCHESTER, N. Y.

A. BRIGHTON PLANT

Grit chamber.—Sewage is received at the plant through a 24-inch gravity line. This discharges into a small distributing chamber from which it can be diverted into any one of three parallel grit chambers by shutter gates opening in three directions. The middle chamber has a straight flow throughout, but the sewage enters the two side chambers perpendicular to their longitudinal axis. In every case, however, the sewage passes through a vertical shutter distributing baffle with adjustable openings into the grit chamber proper. The over-all outside dimensions of the three grit chambers with their inlet and outlet channels are 33 by 21 feet. The effective dimensions are, however, much smaller. For each chamber, neglecting the inlet and outlet channels and termininating at the foot of the screens (to be described later), the effective length is but little over 9 feet and the width 4 feet. The bottom is in the shape of a trapezoidal hopper, into which fits a 1-yard container which is removable by a chain-falls on a traveling crane. Over this is a false bottom made of a longitudinal wooden grating of 2-inch bars with 1-inch clear openings. This is pivoted at the upstream end, the downstream end being adjustable vertically to vary the depth of the channel with the flow of the sewage.

Screen.—Near the outlet of the grit chambers the sewage passes under an adjustable scum board and onto an inclined cast-iron bar screen, with clear openings of $\frac{11}{16}$ inch.

After the plant had been operating a short time it became evident that very little grit was being carried in suspension. One grit chamber was, therefore, remodeled to act merely as an inlet channel to the screen. The width was reduced and the velocity thus increased. The plant is at present operating without grit chambers, the unconverted chambers being held to take care of any unusual situation, when an excessive amount of grit is carried into the sewage through a break in the sewers, or at time of new construction work.

From the screens the flow is over a spillway into a common discharge chamber. There is also an emergency spillway around the screens into this chamber to prevent overflow in case the screen should become clogged. The outlet of the discharge chamber is a 16-inch cast-iron pipe with a flaring mouthpiece which leads to the Pelton water wheel in the operating house 69 feet below and a distance of about 500 feet.

In case the wheel should be stopped, the discharge chamber at its head would overflow into a brick manhole from which is run a 12-inch overflow pipe to the operating house, but around the Pelton wheels. In the operating house there is a 6-inch valve-controlled connection between the two pipes, so that the 16-inch pipe can be blown out through the 12-inch one.

Two 10-inch pipes, reducing to 6-inch, are taken off the 16-inch pressure line to the water wheels, only one of which has, however, been installed. The discharge from the water wheel enters the chamber which also receives the flow from the 12-inch overflow pipe, and from there is sent to the Imhoff tank. The gates are so arranged that the sewage can be sent into either end of the Imhoff tank or can by-pass it altogether. There is also an overflow weir from the discharge chambers of the Pelton wheel to the effluent channel from the Imhoff tank.

All valves and partitions of the inlet and outlet channels of the Imhoff tank are controlled from and contained under the floor of the power house.

Imhoff tank.—The Imhoff tank is a combination of the circular and rectangular types. The side walls 32 feet 6 inches long are parallel, but the two ends are semicircles with 15-foot radii. The over-all, inside dimensions of the tank are: Length, 62 feet 6 inches; width, 30 feet; maximum depth, 37 feet to the top of t sides and 40 feet to the top of the gas vents.

There is but one flow chamber, 24 feet wide, with an effective length of 60 f and maximum depth of 19 feet. The flow line is 2 feet below the top of the ta No curvature is made in the side walls of the flow chamber; they terminate i the curved ends of the tank and extend 3 feet above the top of the tank. The are vertical for 9 feet below the flow line. The bottom is of rather unusual design and construction. From the bottom of the vertical sides it has a 1 to 1⅛ slope toward the center for a horizontal distance of 3.2 feet. Here it makes, with a triangular beam, a slot with a 6-inch slant opening. The apex of this beam is 1.6 feet above and one-half foot inside the slot. The inside slope of this beam is extended at the same slope of 1 to 1⅛ to a 6-inch slant with slot formed with a central triangular beam. In this way the bottom has four slots. The advantages claimed for the design are:

(1) A maximum settling area with a maximum sludge digestion volume for a given width and depth.

(2) The bottom can be cast in reasonable size slabs of uniform size at a convenient place where the best possible finish can be put on them, and when cured, can be set in the tank.

Outside of an inlet and outlet scum board there are no baffles in the flow chamber. The scum boards are made of galvanized iron and extend down 3 feet. Attached to the bottom of these boards are extensions of one-fourth inch wire mesh for the purpose of catching particles carried down by the current below the solid portion.

The inlet and outlet weirs are 10 feet long. The total capacity of the flow chamber from the flow line to the apex of the lowest slot is 20,400 cubic feet, or 153,000 gallons.

Below the flow chamber the digestion chamber has a total depth of 16 feet, of which 6 feet is in the hoppers. There are two hoppers separated by a baffle wall. Each hopper is 30 feet wide and 30 feet long at the top, one end being semicircular with a 15-foot radius to conform to the ends of the tank. The bottoms slope to a point on a 2½ to 1 slope. Each hopper has an 8-inch cast-iron outlet pipe which starts very close to the center of the hopper, centering 7 inches inside of the transverse center lines, and extends without bends to the side of the tank through which it is carried by a Y connection, the main pipe also passing straight through the tank wall to above the flow line for cleaning purposes. A 5-foot hydraulic head is available over the outlet.

Around and halfway up the hoppers is provided a 2-inch pipe perforated on the bottom which is available for use with both air and water for agitation of a sludge. A half-inch pipe connection is also provided for introducing both air and water into the outlet pipe. The total capacity of the sludge chamber from the bottom of the hoppers to the overlap of the lowest slot in the flow chambers is 18,025 cubic feet.

Dosing tanks.—From the Imhoff tank the sewage passes to the siphon chamber through the effluent channel under the operating house. The siphon chamber discharges into the dosing tanks alternately. For operating purposes the siphon chamber actually extends back and includes a section of the effluent channel. At the end of the effluent channel the sides flare out from an inside width of 4 feet to an inside width of 27 feet in a length of 11½ feet. Within this triangular chamber are installed four 20-inch Miller siphons each rated to discharge 5,000 gallons per minute under a 2-foot head. Only two of these are in use at present, the other two being held for future filter installation.

These siphons operate in rotation, each discharging into a separate dosing tank for one filter unit. The dosing tanks are 6 feet wide, 18 feet long, and 5½ feet deep at the inlet, sloping to 10½ feet at the outlet, where the main feed line to the filter leaves the tank flush with the bottom. Both the siphon chambers and dosing tanks are covered by a concrete platform roof.

The effluent from the Imhoff tank collects in the siphon chamber, backing up in the tank effluent channel till the level at which the siphon acts is reached. The proper siphon then discharges into its dosing tank which at that time is empty. The flow continues until the siphon breaks after discharging the stored or backed up sewage, plus the flow from the Imhoff tank during the period of discharge. It is thus evident that the duration of and volume of any dose depend upon the rate of flow from the tank. In heavy flows, therefore, the doses applied to the filters not only occur more frequently but are of longer duration.

As the dosing tanks are empty at the moment of discharge of the siphon, the nozzles start operating under a minimum head. This quickly builds up as the flow through the siphon is in excess of that through the filter nozzles. The nozzle discharge increases while the siphon discharge decreases as the head over it is lowered. After the siphon breaks, the head on the tricklers gradually drops till the dosing tank is empty.

As will be discussed later, the surface of the filter is sloped away from the dosing tank to compensate for the loss of head in the distributing lines. The hydrostatic head on the filters runs from 0 to 7 feet and back to 0 during each dose.

As stated before in connection with the siphons the dosing tank installation is for four filter units, but only two of them have been installed at the present time.

Trickling filters.—The filters are of the trickling type. There are two units each 189 feet long and 115 feet wide, giving an area of a half acre each. The nozzles are of the Columbus type, but during the winter a spreader is used to give a flatter trajectory similar to the Worcester nozzle. These are spaced 14 feet 4 inches center to center staggered on parallel lines to give the proper diagonal distance of 14 feet 4 inches between nozzles on parallel lines. There are a total of 113 sprinklers on each unit, the outside ones being 7 feet 6 inches from the walls.

As stated before, to partially compensate for frictional losses in the distribution system, the surface is laid with a slope of 1 foot in 200 in both the longitudinal and transverse directions.

The distribution system for each filter consists of a 12-inch cast-iron main line located in the filter gallery which lies between the two filters. From this line fifteen 5-inch laterals are taken, each feeding 7 or 8 sprinklers set in 2-inch cast-iron risers. Each lateral is separately controlled by a valve in the filter gallery and has a quick-opening valve at its lower end whereby the line is flushed daily. The laterals are supported on piers 3 feet high.

The filter gallery proper is 8 feet wide and over 6 feet high, well lighted with a window over each lateral connection. Within this gallery at its lower end is located a Gould triplex pump, gear connected to a direct-current motor for pumping the effluent from the secondary sedimentation tanks around the plant for use where it can be substituted for water. In designing this gallery particular attention was given to arranging pipes so as to use standard fittings instead of specials.

The filtering material is dense limestone of a specified uniform 1-inch size, averaging 6 feet in depth. Care was taken to secure the size specified.

The underdrains are laid lengthwise with the bed, at right angles to the distributors. They consist of 6-inch tile laid on a 1 to 200 slope, and spaced 7 feet 2 inches apart, the bottom being sloped toward them. Each drain discharges direct into the secondary sedimentation tank. It is possible to turn a flushing stream of water or final plant effluent into the upper ends of the drains and the lower ends are accessible for rodding.

With the present sewage flow there is no need of operating the entire filter area continuously. In 1919, with an average flow of about 1.1 m. g. d., only 66 per cent of the nozzles were in service. It is customary to allow certain sections of the filter to lie idle each day, but to rotate these sections so that the entire filter is benefited by the available excess capacity.

Secondary sedimentation tanks.—Following the trickling filters and receiving the effluent direct from the individual underdrains are the two secondary sedimentation tanks, one for each filter. These tanks are 115 feet 4 inches by 30 feet, with a depth sloping from 2 feet to 4 feet. The inlet side of the tanks is adjacent to the filters and the outlet end is along the filter gallery. This places the outlet end adjacent to and at right angles to the inlet. The sewage from different drains from the filters thus has settling or flow distances varying from but a few feet to over 115 feet. The outlet is in the form of a weir extending across a 30-foot end of the tank. This weir is protected from scum, and, in the wintertime, from ice by a curtain wall extending about 18 inches below the flow line. The available capacity of each tank is 75,000 gallons, or about two hours with the filters operating at 2 m. g. d.

Six-inch valved pipes to the effluent channel enable the complete drawing off of the sewage, after which the sludge can be flushed or pushed to a 2-foot sluice gate and discharged.

Sludge disposal.—Under the original plans a two-unit sludge bed was constructed adjacent to the Imhoff tank. Each unit is 30 feet by 56 feet. The bottom consists of 6 inches of puddled clay. Over this is laid 6 inches of three-fourth inch broken stone, then 4 inches of sand and gravel under 1 inch, and finally the surface of 2 inches of screened sand.

The bed is drained by 2-inch tile on a 0.5 per cent grade toward the dividing wall, where there is provided a 6-inch collector which discharges into the secondary sedimentation tanks.

With an area of 3,360 square feet and an assumed population, allowing for growth of 10,000, the design was based on about one-third square foot per capita.

In 1918 the use of the sludge beds was temporarily dispensed with and a 12-inch line laid from the tank to a hollow to the north of the plant, where sludge was lagooned. No objectionable condition has resulted from this procedure, the lagoon being well screened by trees from the plant or from any other territory likely to be affected.[3]

Final effluent pipe.—Sewage from the secondary sedimentation tanks are carried by a 12-inch pipe about 1,000 feet to a submerged outlet in the main channel of Irondequoit Creek three-fourths mile above the head of Irondequoit Bay, an arm of Lake Ontario. For most of this distance there is a second pipe laid parallel and 2 feet distant from the first. This is a provision for the future, but serves as a spare in case of trouble in the first pipe.

B. IRONDEQUOIT PLANT

Sewage is received at the plant in a rectangular sewer 10 feet wide by 4½ to 5½ feet deep, the bottom being curved on a 13-foot radius.

Included in the sewerage system tributary to the plant are two sand catchers with coarse bar screens. During the years 1918 and 1919, an average of 100 cubic yards per year was removed from these.

The flow of sewage is measured through a Venturi meter about 800 feet from the inlet to the plant.

Screens.—At the treatment plant the sewage passes through one of two bar screens with 3-inch clear openings into the grit chambers, each screen serving three grit chambers.

Grit chambers.—These are arranged in two parallel batteries of three chambers each, all independently controlled by 36 by 60 inch sluice gates and all with separate outlet channels. While there are six chambers in the installation only the four inside ones are used, the two outside ones being held for future enlargement of the plant. With the excess capacity over present requirements of the four operating chambers and the two unused ones, there is capacity available to double the size of the plant.

Each chamber is 90 feet long, 10 feet wide, and 9 feet deep. A 2-foot-wide channel in the center of the bottom extends the entire length of the chamber sloping both ways to a 16-inch drain at the middle. This channel contains an 8-inch tile drain overlaid by 1⅓ to 1½ feet of sand and gravel, by which it was intended to drain the grit before removing it. The remainder of the bottoms of the chambers is vitrified brick.

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[3] Since survey was made the use of the prepared sludge beds has been resumed.

For cleaning the chambers, tracks have been laid between them for an "A" frame derrick. With this the drainage system, as described above, is not used now cleaning being done with the chambers standing full of sewage.

The bottom of the grit chamber is about 2 feet 9 inches below the level of the outlet channel. It was stated that grit should not be removed till it was about 3 feet deep. Up to this point considerable sludge is deposited at the outlet and it is necessary to displace this with grit and to allow it to wash out before removing grit.

Fine screens.—The sewage from the grit chamber enters short channels 21 feet long, 5 feet wide, and 6 feet 3 inches deep, which discharge onto Riensch-Wurl screens. These screens are arranged in parallel, there being no connection between them, and each is served by a grit chamber which can not serve any other screen. There are four screens in place at the present time, two with one-sixteenth by 2 inch slots, one with one-eighth by 2 inch, and one with three-eighths by 2 inch. The screens are all 12 feet in diameter with a frustum of a cone at the center, and are inclined 30° from the horizontal. They are of the bascule type suspended from steel bridges, with no submerged bearings. Each screen is driven by an independent motor.

The three-eighth and one-eighth inch screens were originally used as a preliminary treatment to Imhoff tank sedimentation during normal flow and the two one-sixteenth inch were used at times of storm flow and constituted the entire treatment of the excess storm flow at such times, the effluent by-passing the Imhoff tank and going direct to Lake Ontario. At the present time either set is now used ahead of the Imhoff tanks.

The screens are cleaned by brushes on revolving spider arms which rotate, carrying the brushes over the surface of the screen exposed above the sewage. The cone section is cleaned by brushes which deflect the screenings to the plate section of the screen, where they are picked up by the revolving brushes mentioned above.

The brushes carry the screenings to a belt conveyor which drops them into a hopper from which small cars carry them to the screenings dump.

The one-eighth and one-sixteenth inch screens which have been operating three years showed considerable evidence of wear, especially on the cone. Grooves are cut in the metal by the brushes rubbing over the surface. Undoubtedly some sand or grit is picked up and held on the screens and some becomes bedded in the brushes. It was estimated that in another three years, making six years in all, the plates would have to be renewed. A set of brushes was stated to last six months.

Connecting channels.—The effluent channels from the screens, 5 feet wide by 7 feet deep, unite to form the influent channel to the Imhoff tanks. Each effluent channel is controlled by a 60 by 60 inch sluice gate. There are two channels connected by gate-controlled openings. One feeds the Imhoff tanks already constructed, and the other is for a duplicate set of tanks to be constructed when conditions require them. The latter may also carry storm water excess by-passing the tanks.

These channels are 494 feet long, 7 feet wide at the inlet, reducing after each inlet to two tanks to a final width of 2 feet. The depth is 6 feet for the entire length and the bottom is flat.

From this main feed channel the laterals are run to the tanks. These are 2½ feet wide by 6 feet deep. They connect with the tank at one near
and discharge into either a channel running across the near end
from which the sewage is taken over a weir or into a channel

length of the tank to an inlet channel across the far end similar to the one across the near end. Whichever one is the inlet, the other one serves as the outlet or effluent channel. The flow into the channels from the main feed channel is controlled by float-operated sluice gates so that each tank gets its proper proportion of the flow. There are two effluent channels from the tanks, one at the center and the other at the corner, adjacent to the influent channel from the main feeder. These channels lead to the main effluent channel located beneath the lateral feed channels.

Flow is reversed by quick-acting sluice gates. By-passing may be done from the main influent to main effluent channels.

The main effluent channel is 10 feet 6 inches wide by 1½ feet deep at the inlet end and 4 feet deep at the outlet. It is divided into two sections, one 3 feet and the other 6 feet wide, by an overflow weir wall. The normal flow is taken by the 3-foot channel, but when its capacity is exceeded the surplus flows over the dividing wall into the 6-foot channel.

Imhoff tanks.—There are in all 10 tanks arranged in five units of 2 each, but each tank is entirely independent. Sewage enters the tanks over 23-foot weirs located at both ends of the tanks and serving either as inlet or outlet weirs depending on the direction of flow in the tanks.

The tanks themselves are 110 feet long 35 feet wide and 39 feet deep. The flow line is 5 to 6 feet below the top of the tank.

Each tank has two flow channels 10 feet wide and 16 feet deep. Of this depth, the sides are vertical for 10½ feet and then slope on a 1 to 1.4 slope for 5½ feet to the slot. As stated before, however, the crest of the weir is 5½ feet below the top of the tank, so that there is available for sewage a depth of only 10½ feet. The sludge slot is of the double type, formed by the two sloping sides with the sides of the triangular beam running longitudinal with the tank. The clear opening is 8 inches.

The total volume of each flow channel is 15,300 cubic feet, but, as the flow line is so low, the available capacity to the crest of the weirs is only 9,240 cubic feet, or 69,000 to 70,000 gallons. The working capacity depends upon the head on the weirs.

The digestion or sludge chamber of each tank is 35 feet wide and 21 feet deep; of this depth 8 feet is in the hoppers, of which there are three, each 35 feet square on the top, and 3 feet 9 inches by 3 feet on the bottom, the slope being 1 to 2. All the digestion chambers are connected by openings in the walls between the hoppers, which, except for this opening, are solid across the entire tank below and around the flow channels. The opening is 8 feet high by 35 feet wide at the top of the hopper where it extends across the tank, but its sides slope to an 18-foot width at the top. Each hopper has an 8-inch sludge pipe extending diagonally upward through the side wall and discharging into a channel between each of the two tanks of each unit. Around each hopper are two water lines of 1½-inch perforated pipe. These are located vertical distances of 1 and 6 feet from the bottom of the hopper. These are used regularly to agitate sludge and when removing it, and are considered essential.

Each tank has three gas vents, one on each side, running the full length of the tank, 2½ feet wide, and the third, 3½ feet wide, down the center, but lacking 10 feet at each end.

There are two scum boards located about 12 feet from each end and extending down about 12 inches. Outside of these there are no baffles.

The sludge compartment has a total capacity below the overlap of the slots of 57,500 cubic feet.

The outlet to the tanks has already been described under "connecting channel."

Sludge treatment.—Each unit of two tanks is served by eight sludge beds 44 by 44 feet, four on each side of a concrete trough which connects with the sludge channel, already described with the Imhoff tanks, by a 24-inch cast-iron pipe, about 33 feet long. The pipe and trough are laid on a 2 per cent grade. Sludge is discharged onto the center of the bed through an 18-inch opening controlled by stop boards in the side of the trough. The sludge drops onto 4 by 4 foot concrete splash plates.

The material of the bed consists of 2 inches of fine sand, 3 inches of coarse sand, 8 inches of gravel, and 6 inches of broken stone. Drainage is provided by 3-inch tile toward which the bottom slopes from both directions. These tile are laid on 8-foot centers and lead to a central drain located in a depression between two beds.

This depression between the first and second and the third and fourth beds of each row is 7 feet deep, about 4 feet below the bottom of the beds, and 9 feet wide. In this is laid a narrow-gauge track for sludge cars. The bodies of the cars are picked off their frame by a gantry crane traveling on tracks on the retaining walls of the depression between the beds and placed on the bed, where they are filled by hand. The crane then replaces them on their frame and they are hauled to the sludge dump by small electric locomotives driven by storage batteries.

There are two sludge dumps, one back of the plant, the other a tipple at the front of the plant from which sludge is dumped direct from the cars into wagons or trucks of farmers, who use the sludge as a fertilizer, paying a small sum for it. They also haul from the dump, but it is not nearly as conveniently situated.

Power development.—The divided tank effluent channel, already described, discharges into two steel effluent pipes. The storm-flow 6-foot channel outlets into a 5½-foot outfall pipe which extends 7,000 feet into Lake Ontario, terminating in a submerged timber crib in water 50 feet deep. The 3-foot wide channel carrying the normal flow discharges into a 4-foot steel pipe or penstock of the hydroelectric plant. This plant has two 75-kilowatt generators which can furnish power for the crane at the grit chamber, the screens, the crane for the sludge beds, lighting, charging the storage batteries of the electric locomotives, etc. Power is also available from a public supply and is used more or less. The tail race of the power plant enters the 5½-foot outfall pipe.

By-passes.—These have been described at points at which they occur in the plant. The flow after leaving the grit chamber, the screens, or the tanks, or both, can be by-passed.

Laboratory.—The laboratory facilities are exceptionally good, both as regards space and equipment. They are located on a mezzanine floor which extends over part of the greenhouse. The laboratory work for both the Brighton and Irondequoit plants is done here.

XI. San Marcos, Tex.

The sewage enters the treatment plant through a 12-inch cast-iron pipe. This material was used, as it was necessary to carry the outfall across the San Marcos River on a trestle.

After passing through a small box inlet chamber set in the 12-inch line, the sewage is discharged into a septic tank.

Septic tank.—This tank was originally constructed as a storage tank for disposal of sewage by broad irrigation, but, after the construction of the present activated sludge plant, it was utilized to remove very coarse material which was found to give trouble in the aeration tank and return sludge line.

The tank itself is circular, 40 feet in diameter and 10 feet deep with an available depth below the flow line of about 8 feet. This gives an available sewage capacity of 10,000 cubic feet, or 75,000 gallons. The tank is plain in every respect, with flat bottom and no baffles.

The sludge outlet is a 6-inch pipe connected to a 6-inch centrifugal pump, belt connected to a gasoline engine. It is but rarely used, however, sludge having been removed but once in the past three years.

The sewage outlet is a 12-inch pipe, around the opening of which is a box frame about 3 by 3 by 2 feet covered with one-fourth-inch mesh galvanized wire screen. As the outlet is located only about 15 feet, chord distance, from the inlet, the period of detention is probably very short, certainly much less than the size of the tank would indicate. It is sufficient, however, to remove rags and gross suspended solids, and thus relieve the activated sludge plant of considerable burden and prevents clogging of the return sludge pipe.

Aeration tank.—This tank is 39 feet long, 16 feet wide, and 10 feet deep from the top of the tank to the filtros plates at the bottom. The sewage enters through a 12-inch pipe located at one corner. Three 3-inch walls divide the 16-foot width into four channels, the two outside 3 feet 10½ inches and the two inside 3 feet 9 inches wide. Openings, 3 feet wide by 7 feet deep, are left in these walls at alternate opposite ends of the tank to connect the four channels in series, thus giving a total flow length of about 150 feet.

The walls of the channels are vertical for a depth of 7 feet, where they slope in to form hoppers. These hoppers, built on 3-foot centers, are 3 feet deep with top areas of 3 feet by 3 feet 10½ or 9 inches and bottom areas 12 by 12 inches.

The total capacity of the tank is 4,750 cubic feet and the available sewage capacity about 3,840 cubic feet or 28,800 gallons.

Air distribution.—Air comes from the blower in a 5-inch pipe. This is increased to 8 inches and runs as a header parallel with the length of the aeration tank, and about 3 feet from it. Every 3 feet, 2-inch wrought-iron distributing lines are taken off. These drop along the outside wall to the bottom, where they enter the concrete bottom and run across the tank encased in concrete. At the center of each channel risers enter the bottom of each hopper and terminate in a small chamber below the filtros plates. These plates form the bottom of the hopper and are cemented in with sulphur. This arrangement gives 13 lines, each feeding 4 filtros plates, or a total of 52 plates. The 2-inch feed lines continue through the tank to the clear on the far side, where they enter a 2-inch collecting pipe which runs on about a 4 per cent grade into a manhole located close by and is closed by a 2-inch valve.

By this means it is possible to drain any water from these lines. To remove accumulations of water in the space below the filtros plates, a three-fourths-inch drain is laid across the tank under each row of plates, on about a 4 per cent grade, to the manhole already mentioned, where it is provided with a valve.

After the plant had been operating for some time several of the filtros plates became clogged. To provide aeration at these points a 2-inch line from the main 8-inch air header was laid on the top of the dividing wall between channels 1 and 2, and seven one-half-inch pipes run down from this to within one-half inch of the top of the clogged plates. The air at these points, therefore, does not pass through any plates, but is discharged downward against the top of them. The distribution, however, appears to be very satisfactory.[4]

For the sedimentation tank, described below, a three-fourths-inch line is run from the main 8-inch header into the tank about 18 feet down from the top and turned up into the sludge pipe. The end is increased to 3 inches to fit the 3-inch sludge pipe and a brass plate with one twenty-fifth-inch holes soldered over the top of the 3-inch bushing. The air is discharged through these holes into the

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[4] Since the survey the clogged plates have been replaced.

3-inch sludge line, the perforations breaking up the air and effecting smooth and regular action of the pump without violent splashing and irregular shooting of sludge from the outlet.

Air is provided by a No. 10 Connersville blower, 6 by 10, with a rated displacement of 760 cubic inches of free air per revolution. During the period of the tests the average speed was 564 revolutions, or 248 cubic feet of free air per minute. The blower is belt connected to a 7½ horsepower Westinghouse motor and discharges to a tank, 24 inches in diameter and 24 inches high, the top of which is filled with excelsior to screen the air. From the tank the air passes through a 5-inch line to the 8-inch feeder already described.

Secondary sedimentation tank.—This tank is 20 feet long by 10 feet wide at the top and 25 feet deep. The end walls are vertical to a depth of about 2 feet where they slope in on an almost 2½ to 1 slope to the bottom which is 15 inches wide. The sides are vertical to a depth of 7 feet where they slope to a depth of 7 feet on a 2 to 1 slope to a 3-foot width. Below this they are vertical for 9½ feet where they again slope 18 inches to a 15-inch bottom.

The inlet is a 12-inch pipe in the corner adjacent to the end of the fourth channel of the aerating tank. The outlet consists of twelve 2-inch pipes turned up and capped by 2-inch tees bushed down to 1 inch. While there are twelve 2-inch outlet pipes available, only five are used. The other seven are capped and held in reserve should any of the five active ones clog. The openings are located to give a flow line about 2 feet below the top of the tank. All outlet pipes are collected in a header outside the tank and discharged into an open drain about 25 feet from the San Marcos River.

There is one baffle located about 3 feet from the inlet and extending down about 3 feet, leaving a 3-inch space between it and the sloping end wall of the tank. The outlet is protected by a scum board extending down 3 inches below the surface.

The sludge outlet is a 3-inch cast-iron pipe extending vertically down the tank, about 16 feet, to a Y. From the branch of this Y a 3-inch line goes to within about 9 inches of the bottom of the tank, while the straight end extends down about 3 feet and is closed by the plate on the end of the air line already described. Just above the top of the tank a 4-inch line is taken off at a T and run to the inlet of the aeration tank, discharging near the surface and directly over the first iltros plate. There is no sludge reaeration tank.

Sludge disposal.—Because of the presedimentation in the septic tank, the amount of sludge to dispose of is relatively small for an activated sludge plant. The sludge from the septic tank has to be removed only occasionally, because the storage available is very large for the sewage flow.

For the surplus activated sludge there are provided 2 sludge beds each 12 by 12 feet, made of cinders. Only one bed has underdrainage. In addition to these beds a small amount of sludge has been run into a small low area adjacent to the plant.

Overflows and by-passes.—At times of very heavy flows carrying considerable infiltration water, the small inlet box may overflow and the sewage spill over the ground to the creek. At this point it is also possible to by-pass the septic tank, sending the sewage direct to the aeration chamber. When the plant was first built the septic tank did not enter into the treatment.

Buildings.—The motor and blower are housed in a small frame building which was at one time also used as a laboratory to make a few simple tests. These have since been discontinued so that the building is now used only as a tool and machinery house.

XII. Sherman, Tex.

Sewage is received at the treatment plant in a 24-inch sewer on a 0.25 per cent grade which discharges into the screen chamber.

Screen chamber.—This chamber is 11 feet 9 inches long, 2 feet wide, and 2 feet 8 inches deep. The screen is 6 feet 6 inches long, 2 feet wide, set at an angle of 18° with the horizontal. The openings are 1½ inches clear between bars. Screenings are raked up by hand and deposited on a bar grating adjacent to the screen where they can drain. They are then thrown to the side of the chamber and later wheeled to a dump.

In one side of the screen chamber an 18-inch weir with its crest 4 inches below the top of the screen provides an overflow for excessive flows or when the screens are clogged. The weir also has a sluice for by-passing all the sewage. The effluent enters a small chamber which discharges through a 15-inch sewer pipe to Town Branch, a tributary of the Red River.

Grit chamber.—The screen chamber discharges direct into the grit chambers. There are three of these in parallel with sluice gates at both ends. All are 57 feet long, and 2 feet 9 inches deep, but two are 18 inches wide, while the third is 2 feet. The bottoms are level but with a groove or channel 1 foot deep by 9 inches wide on top and 8 inches on the bottom. These hold a 4-inch tile drain laid in gravel and leading to a small discharge chamber, where they end with gate valves. The discharge chamber itself connects through an 8-inch vitrified pipe to a low-lying area selected for sludge beds, which, however, were never constructed. The grit is removed by hand about every three weeks.

Inlet channel.—The discharge from all three grit chambers enters a short chamber 8 feet long, 7 feet 2 inches wide, by 2 feet deep at the inlet and 4 feet 6 inches wide by 3 feet 6 inches deep at the outlet. This chamber empties into two channels 1 foot 10¾ inches wide by 3 feet 6 inches deep which lead to the aeration tanks.

Aeration tanks.—At the present time only one of the two aeration tanks is complete. The other still lacks the filtros plates and air-distribution pipes. With this exception, they are duplicate units. However, as this one is not available, the plant is considered as having but the one unit.

The aeration tank is 24 feet 4½ inches wide, divided into three sections by two baffles starting from alternate opposite ends of the tank and stopping to allow an 8-foot opening between adjacent sections. They are thus arranged in series, giving a total flow length of about 200 feet, the total length of the tank being 75 feet. The total depth of the tank is 12 feet. The bottom consists of V-shaped ridges on 5-foot centers across the tank separated by 1 foot 2 inch channels in which the filtros plates are set. A 6-inch channel cutting the ridges runs the length of the tanks through the center of each section to provide complete drainage to the top of the filtros plates, the channels being connected with the settling tank through a valve-controlled 8-inch pipe from the central aeration section. Sewage enters the tank direct from the inlet channel at one corner and leaves through an opening 3 feet wide at the corner diagonally opposite.

The total capacity of the tank is 19,775 cubic feet. With a water line 2 feet below the top, the available capacity is 16,656 cubic feet or 116,000 gallons.

Air distribution.—The main air line to the tanks is 12 inches. This divides into two 8-inch headers which reduce to 6 inches after supply lines have been taken off for two aeration tanks. The supply lines to the individual aeration channels run lengthwise with the tank over the center of each channel. The supply pipes to the first two channels start at 4 inches but are reduced at several points to a final 2½ inches. Over the third channel the pipe is larger, starting with 5 inches and reducing to 3 at the end of the tank, but it is continued at that size to the center of the sedimentation tank, where it reduces to 1 inch at a needle valve and drops down 12 feet below the top of the tank to the side branch of a Y on the sludge line. From the supply lines over the aeration tank, 2-inch galvanized iron pipes are dropped to the bottom of the tank, where they screw into cast-iron holders in which the filtros plates are set. These holders are 7 feet 5½ inches long by 13½ inches wide and hold five 12 by 12 inch filtros plates. There is an air space of a little less than an inch between the bottom of the holder and the filtros plates extending the entire length of the holder.

The main feeder line, from which the supply lines to the aeration tank are taken, is continued on top of and along the wall between the aeration tank and the reaeration tank. At several points it is reduced from 4 inches to 2 inches. From this line and at 10-foot centers 2-inch lines lead across the reaeration tank, and from these three pipes dropped to filtros plate holders, a pipe to each section in the tank. (See description of reaeration tank.) The holders in this tank are similar in design to those in the aeration tank, but are 5 feet 4½ inches long by 13½ inches wide and hold only four plates.

All drop pipes to filtros plates are independent, each having its own control valve.

Sedimentation tank.—As with the aeration tank two units have been constructed, but only one is available for use.

This tank is 28 feet 4½ inches long, 21 feet 10½ inches wide, and 31 feet 4 inches deep. The two side walls are vertical for 15 feet 3 inches where they slope on about a 1.7 to 1 slope to the bottom, which is 3 feet square. The end walls run on the same slope from the bottom, but as the tank is longer than it is wide, the slope extends up to within about 9 feet 9 inches of the top of the tank.

The inlet to the tank is an opening 3 feet wide cut in the common wall between the aeration tank and the sedimentation tank. This opening is 3½ feet deep, 1½ feet below the flow line of the tank and is located in one corner of the tank. The outlet is over a 3-foot weir.

In the inlet end, a baffle is hung 6 feet from the end of the tank, extending down 6½ feet from the top of the tank or 4¼ feet below the normal water line which is estimated at 2 inches over the outlet weir. The outlet is protected by a scumboard placed 2 feet ahead of the weir.

The sludge outlet is a 6-inch pipe extending down within 9 inches of the bottom of the tank and terminating in a flared mouthpiece 12 inches in diameter. A horizontal 6-inch pipe from a T 2 feet below the top of the tank carries the sludge to the reaeration tank. Sludge is lifted by air which is introduced through a 1-inch pipe into the side branch of a Y set in the vertical 6-inch riser 12 feet below the top of the tank, or 10 feet below the flow line.

The effluent from the tank passing over the 3-foot weir enters an effluent channel 2 feet 1½ inches wide by 4 feet 4 inches deep, connecting with a 15-inch line which unites with the 15-inch overflow line from the grit chambers leading to Town Branch, a tributary of the Red River.

The total volume of the tank is 11,500 cubic feet. With the flow line 2 feet below the top the available volume is 10,000 cubic feet or 75,000 gallons.

Reaeration tank.—This is located alongside of the aeration tank. There is one for each aeration tank, but for reasons already stated only one unit is available.

The tank is 6 feet 7½ inches wide, divided into three channels, each 2 feet ½ inch wide, by 3-inch baffle walls similar to those described under the aeration tank but with end openings of only 2 feet ½ inch. The two channels nearest the aeration tank are 75 feet long, but the third or outside channel extends beyond the aeration tank and overlaps the sedimentation tank by 10 feet, so that it is 85 feet long. Sludge is moved from the sedimentation tank through a 6-inch pipe discharging near the end of the long channel. The tank has a total depth of 12 feet, and of this depth 2 feet 3 inches is in the channeled bottoms, in which the filtros plates are set. There is only one row of plates in each channel, the holders being laid lengthwise with the tank. The outlet is a 2 foot ½ inch opening cut the full depth of the tank through the common wall between the reaeration tank and the aeration tank.

From the bottom of the tank at the inlet end a 6-inch vitrified-tile sludge pipe, controlled by a sluice gate is run to the 8-inch line from the grit chamber drains, which leads to the low land where it was planned to build the sludge beds. There is also an 8-inch valve-controlled connection from the bottom of the tank to the sedimentation tank which permits the draining of this tank and with it the aeration tank to the filtros plates.

Sludge disposal.—It was planned to provide sludge beds in low areas near the Town Branch. These, however, have never been constructed, and sludge is mostly disposed of by discharging it into the Town Branch at times of high water.

Power plant.—The power plant is housed in a concrete building 26 by 22 feet. This contains a Connersville blower, belt connected to a 24-horsepower General Electric Co. motor, having a capacity of 2.1 cubic feet per revolution. This installation is used almost exclusively as a reserve unit since it allows oiled surfaces to come in contact with the air, and oil is carried to the filtros plates. The regular unit consists of a Gordon City Fan Co. water cooled rotary compressor, belt connected to a 25-horsepower General Electric motor.

Air is taken from within the building. A box frame about 6 by 12 by 6 feet is suspended from the ceiling and covered with one layer of cotton flannel. The suction of the blowers extend into this box. Air can enter the building through two roof ventilators which are covered with a brass screen. It is probable, however, that the doors and windows provide as much if not more air than the ventilators.

Air is pumped to a tank, just outside the building, 3 feet 6 inches in diameter and 9 feet high, which is kept under 5 pounds pressure. From this tank the main feeder is taken to the tanks.

Laboratory.—There are no laboratory facilities at the plant nor any owned or controlled by the city.

APPENDIX II

QUESTIONNAIRE FORM FOR THE ENGINEERING SURVEY

[Sheet 1]

DATA RELATING TO THE SEWERAGE SYSTEMS AND THE DESIGN AND OPERATION OF SEWAGE TREATMENT PLANTS AT SOME OF THE LARGER CITIES OF THE UNITED STATES

City.......... Date.............................. Survey by....................

Sewerage system:

1. Total population of city........ Census of 19... Estimated by............
2. Population contributing to treatment plant..........................
3. Sewer connections..
4. Combined or separate..
5. Gradients...
6. Infiltration and leakage....................................
7. Storm overflows...
8. Flushing by hose, direct water connection, flush tank, etc..........
9. Sewers:

Shape	Size	Description
	Inches	
..........feet..	4	....
..........feet..	6	....
..........feet..	8	....
..........feet..	10	....
..........feet..	12	....
..........feet..	15	....
..........feet..	18	....
..........feet..	20	....
..........feet..	24	....
..........feet..	30	....
..........feet..	36	....
..........feet..	42	....
..........feet..	48	....
..........feet..	60	....

10. Miscellaneous and remarks..

[Sheet 2]

City..............................

Sewage pumping:

1. Location of pumping station..
2. Type of pumps...
3. Power equipment...
4. Method of operation, continuous, etc................................
5. Suction well:
    - (*a*) Size and dimensions..
    - (*b*) Screens..
6. Control apparatus...
7. Discharge head..
8. Apparatus for measuring flow..
9. Miscellaneous and remarks...

[Sheet 3]

City ------------------------

Sewage data (at outfall to treatment plant):

1. Volume—
   - (*a*) Dry weather flow--
   - (*b*) Variations--
   - (*c*) Storm waters carried to treatment plant-------------------
   - (*d*) Industrial wastes:
     1. Character--
     2. Treatment of source------------------------------------
   - (*e*) Water consumption---
2. Composition—
   - (*a*) Fresh or stale--
   - (*b*) Floating material---
   - (*c*) Industrial wastes---
   - (*d*) Color---
   - (*e*) Odor--

[Sheet 4]

City ------------------------

Sewage treatment plant:

Sewer outlet at treatment plant—

1. Size and shape---
2. Measuring weirs and recording devices--------------------------
3. Storm overflows--
4. By-passes, type and when used----------------------------------
5. Coarse screens---
6. Miscellaneous and remarks--------------------------------------

[Sheet 5]

City ------------------------

Grit chambers:

1. Number---
2. Design including dimensions------------------------------------
3. Velocity of flow and detention period--------------------------
4. Method of cleaning---
5. Disposal of grit---
6. Volume deposited per million gallons---------------------------
7. Composition of grit—
   - (*a*) Average per cent water--------, average sp. gr.---------------
   - (*b*) Odor--
   - (*c*) General character---
8. Loss of head---
9. Outlet channels to tanks---------------------------------------
10. Miscellaneous and remarks--------------------------------------

[Sheet 6]

City ------------------------

Fine screens:

1. Location and purpose---
2. Number---

3. Dimensions and description—
    - (*a*) Type------------------------------
    - (*b*) Mesh------------------------------
    - (*c*) General------------------------------
4. Capacity----------------gallons per------------------
5. Head required to operate------------------------------
6. Method of cleaning------------------------------
7. Screenings, volume per million gallons, wet------------------
8. Method of drying screenings------------------------------
9. Method of disposing of screenings------------------------------
10. Odor from screenings------------------------------
11. Composition of screenings------------------------------
12. Loss of head through screens------------------------------

[Sheet 7]

City ------------------------

Sedimentation tanks—Primary, Secondary, Sludge digestion:

A. All types except Imhoff—
1. Number and type------------------------------
2. Shape------------------------------
3. Dimensions------------------------------
4. Type of inlet------------------------------
5. Hoppers, number, shape, dimensions, capacity----------------
6. Baffles, spacing, surface or bottom------------------------
7. Scum boards------------------------------
8. Sludge outlets—
    - (*a*) Number------------------------------
    - (*b*) Size------------------------------
    - (*c*) Water pipes in connection with--------------------
9. Sewage outlet, size and arrangement for------------------
10. Velocity of flow, detention period, maximum, minimum, averag

    ----

[Sheet 8]

City ------------------------

B. Imhoff tanks—
1. Number------------------------------
2. Description, shape, inlets, outlets, etc., --------------------
3. Flow chamber—
    - (*a*) Dimensions, capacity------------------------------
    - (*b*) Size and shape of gas vents------------------------
    - (*c*) Slope of incline partitions------------------------
    - (*d*) Width of slot and description--------------------
    - (*e*) Velocity of flow, vertical or horizontal--------------
    - (*f*) Detention period, computed and actual, maximum, m mum, average------------------------------
    - (*g*) Baffles, spacing, surface or bottom----------------
    - (*h*) Scum boards------------------------------
4. Loss of head through tank------------------------------

[Sheet 9]

City ------------------------

B. Imhoff tanks continued—
   5. Digestion chamber—
      (*a*) Dimensions, capacity to slot------------------------
      (*b*) Hoppers, number, shape, dimensions, slope of sides------
      (*c*) Sludge outlets—
         1. Number and size------------------------
         2. Water connections for cleaning------------------
      (*d*) Baffles--
      (*e*) Storage of sludge in tank—
         1. Period------------------------------------
         2. Basis of design, cubic feet per capita-------------
   6. Special apparatus or equipment----------------------------

[Sheet 10]

City ------------------------

B. Imhoff tanks (continued)—
   7. Foaming—
      (*a*) When did foaming begin?------------------------------
      (*b*) How long did it persist?------------------------------
      (*c*) Season of year most active?--------------------------
      (*d*) How stopped or controlled, apparatus or devices used?---- --
   8. Population for which tanks are designed-------------------
   9. Miscellaneous and remarks----------------------------

[Sheet 11]

City ------------------------

Chemical precipitation:
   1. Chemicals used--
   2. Method of application (dry or wet)------------------------------
   3. Apparatus for applying--
   4. Where applied--
   5. Amount applied--
   6. Miscellaneous and remarks----------------------------------

Disinfection:
   1. Chemicals used--
   2. Description of apparatus used----------------------------------
   3. Amount of chemicals used-----------------------------------
   4. Where applied--
   5. Applied continuously throughout the year---------------------
   6. Reasons for disinfection----------------------------------

[Sheet 12]

City ------------------------

Sludge production:
   1. Volume wet sludge in cubic yards per million gallons------------------
   2. Methods of measurement------------------------------------
   3. Per cent water, average, --------; specific gravity average, ----------

4. Physical characteristics—
    (*a*) Color ....
    (*b*) Consistency ....
    (*c*) Odor, when freshly drawn and after drying ....
5. Sludge drying beds description ....
6. Time required to dry sludge on beds. Depth of sludge applied ....
7. Mechanical apparatus for drying sludge—
    (*a*) Description of apparatus ....
    (*b*) Capacity (cubic yards of wet sludge per 24 hours)............
    (*c*) Per cent moisture of dried cake ....
    (*d*) Time required for each cycle of operation ....

[Sheet 13]

City ....

8. Final disposal of sludge—
    (*a*) In lagoons ....
    (*b*) Discharged in water courses ....
    (*c*) For filling ....
    (*d*) For fertilizer (make note of crops raised) ....
    (*e*) Revenues ....
    (*f*) Head over sludge outlet ....
    (*g*) Miscellaneous and remarks ....

[Sheet 14]

City ....

Activated sludge:
1. Sewage aeration tanks:
    (*a*) Number ....
    (*b*) Description of tanks (dimensions, etc.) ....
    (*c*) Description of air diffusing apparatus at bottom of tank ....
    (*d*) Type of blower ....
    (*e*) Volume of air per gallon of sewage ....
    (*f*) Duration of treatment ....
    (*g*) Continuous flow or fill and draw ....
    (*h*) Per cent of activated sludge returned to tank ....
    (*i*) Apparatus for screening air ....
    (*j*) Loss of head ....

[Sheet 15]

City ....

Sludge aeration tanks:
    (*a*) Design of tank ....
    (*b*) Diffusion, apparatus for..........................
    (*c*) Volume of air ....
    (*d*) Time of aeration..................................
    (*e*) Loss of head ....
3. Miscellaneous and remarks ....

[Sheet 16]

City ------------------------

Filters:
1. Type------------------------
2. Number------------------------
3. Area and depth each unit------------------------
4. Filtering medium, size and composition------------------------
5. Method of applying sewage:
    (*a*) Flooding------------------------
    (*b*) Nozzles------------------------
    (*c*) Rate of treatment------------------------
    (*d*) Net rate per 24 hours------------------------
    (*e*) Head on nozzles------------------------
    (*f*) Siphons------------------------
    (*g*) Automatic control devices------------------------
6. Pooling------------------------

[Sheet 17]

City ------------------------

7. Underdrainage:
    (*a*) How constructed------------------------
    (*b*) Slope of concrete bottom------------------------
    (*c*) Arrangement for flushing------------------------
8. Washing or other methods of cleaning------------------------
9. Flies, worms, and other forms of life------------------------
10. Growth on beds and in underdrainage------------------------
11. Condition of filtering media------------------------
12. Odors from filters------------------------
13. Resting of beds------------------------
14. Cowls or similar devices------------------------
15. Loss of head in filters------------------------

[Sheet 18]

City ------------------------

Ultimate disposal of sewage:
1. Receiving body of water------------------------
2. Physical conditions near outlet------------------------
3. Dilution available, dry weather------------------------
4. Use of water below sewer outlet------------------------
5. Miscellaneous and remarks------------------------

[Sheet 19]

City ------------------------

Cost data:
1. Original cost—
    (*a*) Per million gallon sewage------------------------
    (*b*) Per thousand population------------------------
    (*c*) By devices------------------------
2. Modifications cost------------------------

3. Cost of operation and maintenance—
    - (a) Man in charge of plant, title and salary……………………
    - (b) Chemists or bacteriologists, salary……………………
    - (c) Clerks……………………
    - (d) Skilled mechanics, etc., salary……………………
    - (e) Laborers, number, salary……………………
    - (f) Total cost of maintenance per year……………………
    - (g) Interest and depreciation……………………
4. Miscellaneous and remarks……………………

[Sheet 20]

City ……………………

General information:

1. Deterioration of concrete due to—
    - (a) Frost……………………
    - (b) Some constituents of sewage……………………
2. Odors from plants as a whole—
    - (a) At the plant……………………
    - (b) Distance from plant noticeable……………………
    - (c) Seasonal……………………
3. Improvements in receiving body of water after installation of treatment plant……………………
4. Condition of grounds about the treatment plant……………………
5. Extent of farming carried on at the plant……………………

[Sheet 21]

City ……………………

6. What population was plant designed for……………………
7. Are sludge drying beds large enough……………………
8. Modification of sludge beds suggested……………………
9. Night soil dumped into sewers……………………
10. Miscellaneous observation about plant not included under headings……………………

……………………

APPENDIX III

METHODS OF ANALYSIS

METHODS OF ANALYSIS

The methods used are described in detail only where they differ materially from the procedure recommended in the Standard Methods of the American Public Health Association for 1920.

1. *Alkalinity.*—As in Standard Methods using methyl orange and sulphuric acid.

2. *Chlorides.*—As in Standard Methods.

3. *Relative stability.*—As in Standard Methods. Incubators were not available at any place visited. The samples were, accordingly, stored in the dark at a temperature as close to 20° C. as it was possible to find.

4. *Nitrogen as nitrates.*—As in Standard Methods, using the reduction method. The results are reported without any correction for nitrites. For the preparation of Nessler reagent, see under ammonia nitrogen, below.

5. *Settleable solids by volume.*—As in Standard Methods (p. 30). Conical glass vessels of 1,000 c. c. capacity (Imhoff cones) were used for raw sewages and tank effluents. For activated sludge, however, straight-sided cylindrical vessels such as 1,000 c. c. graduates, are preferred.

6. *Suspended matter.*—As in Standard Methods. In the absence of constant temperature apparatus, the Gooch crucibles were dried over a water bath with suitable precautions to avoid moisture from condensed steam. The difference between this method of drying and that of drying at 103° C. is inappreciable.

7. *Ammonia nitrogen.*—As in Standard Methods, using copper sulphate as a clarifying agent. Instead of short tubes, bottles holding about 125 c. c. were used.

During the survey it was noted that difficulty was experienced in the preparation of Nessler reagent. It is thought advisable to give the method for the preparation of the reagent in detail.

REAGENTS FOR THE PREPARATION OF 1 LITER OF NESSLER REAGENT

(*a*) *Iodide solution.*—Dissolve 50 grams of potassium iodide or 45 grams of sodium iodide in 80 c. c. of distilled water.

(*b*) *Hydroxide solution.*—Prepare a 50 per cent solution of sodium or potassium hydroxide. This solution should be prepared ahead of time and allowed to settle for a few weeks before use. The clear supernatant is decanted or siphoned off. For 1 liter of Nessler reagent, 285 c. c. of 50 per cent sodium hydroxide or 400 c. c. of 50 per cent potassium hydroxide will be required.

(*c*) *Mercuric chloride solution.*—About 350 c. c. of saturated solution will be required.

PROCEDURE FOR THE PREPARATION OF NESSLER REAGENT

Add the iodide solution to a bottle calibrated roughly at 1,000 c. c. and then add the saturated mercuric chloride solution in 25 to 50 c. c. portions, with constant shaking, until about 300 c. c. have been added. The reddish precipitate which first forms dissolves more and more slowly. It is of importance that the iodide solution be completely saturated but not very greatly oversaturated with the mercuric chloride. When about 300 c. c. of mercuric chloride have been added, the addition of the mercuric chloride is continued as if in a titration with a very slow end-point, adding 5 c. c. portions with vigorous shaking until the reddish coloration has disappeared. When the end-point appears to be near, the mercuric chloride solution is added in 1 c. c. portions until a precipitate is obtained which persists for one hour. An additional one half c. c. portion should then cause the color to persist overnight, and if it does not, another half c. c. portion is added. When the end-point has been reached, 400 c. c. of 50 per cent potassium hydroxide solution or 285 c. c. of 50 per cent sodium hydroxide is added and the whole made up to 1 liter.

If required for immediate use, the solution may be filtered through asbestos, using suction. For small amounts a Gooch crucible is quite satisfactory. It is best, however, to allow the solution to settle for several days. It should then take on a clear greenish color. The reagent thus prepared improves until the bulk of the precipitate has settled out, after which no improvement with age can be detected. For use, it is decanted or siphoned into a small bottle in order to avoid stirring up the sediment on the bottom of the large bottle.

It is the experience of the writers that the sodium and potassium salts may be used interchangeably—i. e., sodium or potassium hydroxide may be used with either sodium or potassium iodide. The procedure is to be followed somewhat closely, since Nessler reagent, which is not sensitive enough can not be materially improved by the further addition of reagents once the hydroxide solution has been added.

8. *Ether-soluble matter (fats).*—As in Standard Methods. In most cases, however, only 200 c. c. of sewage was used.

9. *Oxygen consumed.*—The procedure followed was essentially that outlined in Standard Methods, with slight modifications to minimize errors due to the deterioration of the reagents and to obviate the necessity of adjusting the oxalate and permanganate solutions to exact or equal strengths.

METHOD FOLLOWED

REAGENTS—(*a*) *Sulphuric acid.*—The concentrated acid, specific gravity 1.84, was used as described below without dilution or addition of permanganate to free the acid from oxidizable matter.

(*b*) *Oxalate solution.*—Potassium or sodium oxalate was used. Ammonium oxalate dissolves slowly and is not superior to the alkali oxalates in keeping qualities. The following amounts are dissolved and made up to one liter in order to obtain an N/80 solution.

0.888 grams of ammonium oxalate, $(NH_4)_2.C_2O_4.H_2O$.
0.838 grams of sodium oxalate, $Na_2C_2O_4$.
1.151 grams of potassium oxalate, $K_2C_2O_4.H_2O$.

(*c*) *N/80 potassium permanganate.*—A N/4 solution is first prepared by dissolving 7.900 grams of $KMnO_4$ in distilled water and making up to one liter. This solution is reasonably permanent and need not be protected in any special manner. It serves as a stock solution for the preparation of the weaker N/80 solution. The N/80 solution is prepared by diluting 50 c. c. of the N/4 solution to one liter. The strength of the N/80 solution will decrease by about 2 per cent in a week or ten days, after which time deterioration will be much more rapid; it should be made up fresh every week. It may be checked against freshly prepared oxalate solution as described in Standard Methods, 1920, page 22, or, more conveniently and with sufficient accuracy for the purpose at hand, against the standard thiosulphate used for dissolved oxygen determinations.

PROCEDURE.—To a 500 c. c. Erlenmeyer flask add 100 c. c. of distilled water followed by 2 c. c. of sulphuric acid, specific gravity 1.84. Then in all cases add 10 c. c. of N/80 potassium permanganate and a quantity of sample such that about 5 c. c. of N/80 potassium permanganate will be required for the back titration after addition of oxalate as described below. The following trial amounts are suggested:

10 to 20 c. c. of raw sewage.
25 to 50 c. c. of filter effluents.

A blank is run, using the same amount of distilled water, concentrated acid, and permanganate as was added to the sample.

The sample and the blank are digested for 30 minutes in an actively boiling water bath. If the amount of sample taken was too large, as indicated by complete loss of color, the determination is repeated. When the digestion is complete, 10 c. c. of the oxalate solution is added to the blank and to the sample, and titration with permanganate is begun as soon as decolorization takes place.

COMPUTATION.—The value found for the blank is deducted from that found for the sample and is a correction for oxidizable substances in the reagents and for any difference in the strength of the oxalate and permanganate solutions. Following the above procedure,

$$\text{p. p. m. of oxygen consumed} = 100\frac{A}{B}$$

where A = c. c. of N/80 $KMnO_4$ required for the back titration less blank, and

B = c. c. of sample digested.

If the permanganate solution is not exactly N/80, a correction can be applied to the result found. Since the same amount of oxalate is added to both the sample and the blank, its strength is not a factor.

10. *Dissolved oxygen.*—The reagents given in Standard Methods, 1920, were used, except that sulphuric acid was substituted for hydrochloric acid in dissolving the precipitated manganese hydroxides. In the preparation of the reagents the sodium salts were used. A detailed description of the method is given below.

The sodium thiosulphate solution was prepared from an N/10 solution preserved by the addition of ammonium carbonate and chloroform after making up to the mark. This solution was reasonably permanent; titrations over long periods of time indicate a rate of deterioration of less than 1 per cent in six months. The N/40 solution is prepared by diluting 250 c. c. of the N/40 solution to one liter. The keeping qualities of the N/40 solution are somewhat improved by the addition of 5 c. c. of chloroform *after* making up to the mark. It will deteriorate rather rapidly, however, and should be made up fresh every few weeks.

The strength of the N/40 sodium thiosulphate may be determined by titration with potassium bichromate or permanganate. The use of potassium biniodate, the acid iodate, $KH(IO_3)_2$, is strongly recommended for this purpose, however. It can be obtained sufficiently pure for direct weighing without further purification, and its keeping qualities both in the dry state and in solution leave little to be desired. A N/10 solution is prepared by dissolving 3.250 grams in distilled water and making up to 1 liter. A N/40 solution is prepared by diluting 250 c. c. of the N/10 solution to 1 liter. The titration is exactly the same as when potassium permanganate or bichromate is used to titrate thiosulphate solutions. Since the use of potassium biniodate appears to be limited, the procedure will be given in detail.

STANDARDIZATION OF THIOSULPHATE SOLUTIONS WITH POTASSIUM BINIODATE

Reagents.—(*a*) Standard potassium biniodate solution, also called potassium acid iodate, Kaliumbijodat, $KH(IO_3)_2$ or $KIO_3.HIO_3$: molecular weight 389.95. A N/10 solution contains 3.250 grams per liter according to the following reaction:

$$KH(IO_3)_2+10\ KI+11\ HCl=11\ KCl+6\ H_2O+(6\ I_2=12\ H)$$

$$N/10\ KH(IO_3)_2=\frac{389.95}{10\times 12}=3.2496=3.250 \text{ grams per liter.}$$

A N/40 solution contains 0.8124 grams per liter. The N/40 solution is best prepared by diluting 250 c. c. of N/10 potassium biniodate to 1 liter. The solubility of potassium biniodate is 1.33 per cent at 15°. A saturated solution would be about N/2.5. Solutions stronger than N/10 are not recommended. Moderate heat may be applied when a solution is being made up; the solution is, of course, allowed to cool before making up to the mark.

(*b*) Potassium or sodium iodide. The dry crystals may be conveniently used, if free from iodates. With an iodide of doubtful purity it is best to use a freshly prepared 10 per cent solution (5 grams of NaI or KI in about 50 c. c. of distilled water).

(*c*) Dilute acid. H_2SO_4, 1 : 10, or HCl, 1 : 5, may be used. HCl should be free from Cl_2.

(*d*) Starch solution.

If acid and iodide are known to be pure:

(*a*) Dissolve a few crystals of KI or NaI, about 0.5 gram, in 50 c. c. of distilled water contained in a 200 c. c. beaker. Solution should be complete since acid added in next step may react with crystalline iodides.

(*b*) Add 2 c. c. of dilute acid; if no color develops, proceed as under "The titration" below.

If any color develops, the acid-iodide mixture contains impurities which must be taken into consideration. If in doubt as to color, or, in any event, with reagents of dubious quality, add a few c. c. of starch solution to confirm. If no color develops, the reagents are of suitable quality. Since the starch would interfere if added at this stage, a fresh acid-iodide solution is made up for the test. The reaction with iodates is as follows:

$$KIO_3+5\ KI+3\ H_2SO_4=3\ I_2+K_2SO_4+3\ H_2O$$

If iodide or acid contain impurities:

(*a*) Add 2 c. c. of dilute acid to 50 c. c. of distilled water contained in a 200 c. c. beaker. 0.2 c. c. of conc. H_2SO_4 may be added instead of the more dilute acid.

(*b*) Add 5 c. c. of 10 per cent iodide solution.

(*c*) Add 1 or 2 c. c. of starch solution.

(*d*) If a color develops, titrate to an end-point with the thiosulphate solution to be tested, noting the amount required. This amount is a correction to be deducted from the final reading.

(*e*) Prepare a fresh acid-iodide solution as in steps "*a*" and "*b*" under this heading, and proceed as under the following:

The titration.—(*a*) Add a little less than 40 c. c. of N/40 biniodate to a 200 c. c. Erlenmeyer flask. Do not wait for burette to drain completely. Less biniodate may, of course, be used, depending on the accuracy which is sought. The procedure as outlined should check within one-tenth of 1 per cent.

(*b*) Adjust and read the burette containing the thiosulphate to be standardized.

(*c*) Pour the acid-iodide solution prepared above *into* the 200 c. c. Erlenmeyer flask containing the measured amount of standard biniodate.

(*d*) Titrate at once with N/40 thiosulphate, avoiding agitation until the bulk of the thiosulphate has been added. The solution is rather concentrated with respect to iodine, and loss is to be guarded against.

(*e*) When a pale straw color is reached, add 1 or 2 c. c. of starch solution and titrate to an end-point.

(*f*) The end-point may be checked by adding enough biniodate to cause the color to return and again reaching an end-point with thiosulphate. If any great accuracy is desired, the sides of the Erlenmeyer flask may be rinsed down with distilled water. It is convenient to use exactly 40.00 c. c. of binoidate since in this case 0.10 c. c. equals one-fourth per cent. Burettes will drain by as much as 0.2 c. c.; hence about 3 minutes should be allowed before taking the final readings.

(*g*) If the iodide or acid contains impurities, the amount found above ("*d*" under "if iodide or acid contain impurities") is to be deducted from the indicated amount of thiosulphate required for the neutralization of the biniodate.

NOTES ON ABOVE PROCEDURE

(*a*) Biniodate solutions are very stable. Under average conditions the N/10 solution will hold up for at least a year.

(*b*) N/40$KMnO_4$ or N/40 $K_2Cr_2O_7$ may be substituted for N/40 $KH(IO_3)_2$. The procedure is exactly the same as outlined.

(*c*) N/10 sodium thiosulphate may be standardized as above, using 20 to 25 c. c. of N/10 biniodate, and twice as much KI and dilute acid, i. e. 10 c. c. of 10 per cent KI (1 gram) and 4 or 5 c. c. of 1 : 10 H_2SO_4 (or 0.5 c. c. of the conc. acid).

(*d*) The amount of iodide used is far in excess of the requirements for the reaction given. If less is used, however, the iodine will not dissolve and may escape by volatilization.

(*e*) Iodide solutions deteriorate rapidly. Chem. Abs., 9:2289, states that KI solutions rendered slightly alkaline with Mg $(OH)_2$ will keep clear in bottles, even in the light, without danger of decomposition.

(*f*) The amount of acid added may be doubled or halved without apparent effect. If too much acid is added, however, the starch will break down (erythrodextrins) forming a red color and giving a poor end-point. If too little is added, the reaction will not proceed as above. In a neutral solution the biniodate is only one-twelfth as strong.

$$6KIO_3.HIO_3 + 5KI = 11KIO_3 + 6I + 3H_2O$$

Hence one molecule of $KIO_3.HIO_3$ liberates only one atom of iodine instead of 12 as shown above.

(*g*) Potassium permanganate may be substituted for potassium biniodate in the above procedure, i. e., once the value of the thiosulphate solution has been determined, it may be used to standardize a permanganate solution.

(*h*) Potassium iodate may also be used to titrate hydroxide solutions, using phenolphthalein as an indicator. In this case, however, the reaction is:

$$KIO_3.HIO_3 + KOH = 2KIO_3 + H_2O$$

i. e., the potassium biniodate has only one-twelfth the value that it possesses as an iodimetric standard. Otherwise stated, 12.00 c. c. of the N/10 solution prepared above (3.250 grams per liter) are equivalent to 1 c. c. of N/10 KOH (or NaOH). The hydroxide solution should be free from carbonates. This adaptation, however, possesses no particular advantage.

PROCEDURE FOR DISSOLVED OXYGEN TEST, USING THE PERMANGANATE MODIFICATION OF THE WINKLER METHOD

The procedure followed was essentially that given in Standard Methods. It has been found, however, that the results are apt to be erratic unless the procedure is adhered to strictly. For this reason the method will be reproduced in somewhat detailed form. Particular importance is attached to the avoidance of an excess of oxalate solution, since with any great excess of this reagent low results are obtained. This effect is counterbalanced somewhat by the addition of an excess of acid just before the titration. For this reason sulphuric acid is used instead of hydrochloric acid.

In many cases it is not necessary to use the preliminary treatment with permanganate. This however, is best determined for each individual waste.

PRELIMINARY TREATMENT WITH PERMANGANATE

(*a*) Add 0.7 c. c. of concentrated sulphuric acid, specific gravity 1.84, to the sample contained in a 300 c. c. bottle. It is important that the amount of acid called for should not be exceeded. The 0.7 c. c. portion, for that reason, is best added with a 2 c. c. pipette.

(*b*) Add 1 c. c. of N/5 $KMnO_4$, unless experience shows that a larger amount is consistently necessary for the particular sample being tested. The N/5 $KMnO_4$ need be but approximate.

(*c*) Shake well and allow to stand for 20 minutes.

(*d*) If the amount of $KMnO_4$ added as in "*b*" appears to be insufficient after the sample has stood for some time, add more N/5 $KMnO_4$ in 0.5 c. c. portions with shaking and suitable delay between additions. The attempt should be made to keep the amount of permanganate added down to a minimum.

(*e*) After the sample has stood for 20 minutes in the presence of an excess of permanganate, remove the stoppers and add 0.5 c. c. of 2 per cent potassium oxalate ($K_2C_2O_4.H_2O$). This solution deteriorates rapidly and should be made up fresh at least every week. Shaking is necessary for the proper distribution of the oxalate.

(*f*) An excess of oxalate is to be avoided for two reasons:

1. The time of decolorization is lengthened when too large an excess of oxalate is added.
2. An excess of oxalate lowers the apparent oxygen content of the sample.

(*g*) If after standing for a few minutes the color of the permanganate still persists, an additional 0.5 c. c. of 2 per cent oxalate is added. Unless the amount of N/5 $KMnO_4$ added has been excessive, this second portion should induce complete decolorization.

(*h*) If a decided excess of oxalate is added, the color due to the permanganate will be quite unchanged until decolorization is almost ready to take place; the sample will assume a brownish color if the amount of oxalate added was insufficient.

(*i*) When the permanganate is fully decolorised, add the Winkler reagents in the following order. Do not add less than the indicated amounts.

> 1 c. c. of manganous sulphate solution and 3 c. c. of alkaline-iodide solution. The manganous sulphate solution contains 480 grams of $MnSO_4.4H_2O$ or 400 grams of $MnSO_4.2H_2O$ per liter. The alkaline-iodide solution contains 700 grams of KOH (or 500 grams of NaOH) and 150 grams of KI (or 135 grams of NaI) per liter.

If the preliminary treatment with permanganate as outlined above has not been used, the test is started with the addition of 2 c. c. each of the manganous sulphate and alkaline-iodide solutions. The subsequent procedure is the same in either case.

(*j*) Shake well to neutralize the acid as fast as possible and to distribute the precipitate uniformly throughout the bottle. The precipitate is then allowed to settle until contained in the lower half of the bottle and the bottle again shaken. If a clear supernatant is not obtained, the shaking may be repeated.

(*k*) Add 2 c. c. of concentrated sulphuric acid, specific gravity 1.84. The acid is allowed to flow down the neck of the bottle.

(*l*) Shake well, since the liberated iodine diffuses but slowly. It should be uniformly distributed throughout the bottle before any is withdrawn for titration.

(*m*) If the preliminary treatment has been used, pour out 101.9 c. c. of sample into a flask calibrated to hold that amount. The correction of 1.9 c. c. is based on the assumption that the reagents are entirely devoid of oxygen;

0.7 c. c. of H_2SO_4
1.0 c. c. of N/5 $KMnO_4$
3.0 c. c. of alkaline-iodide solution
1.0 c. c. of manganous sulphate solution
5.7 c. c. added to a 300 c. c. bottle requires a correction of 1.9.

This assumption is only partly correct, since some of the reagents undoubtedly contained some oxygen. No correction is made for the addition of oxalate solution, since this is presumably saturated with oxygen. No correction need be made for the acid added just before the titration, since no dilution of the sample is involved. The correction for the reagents added somewhat balances the slightly lower results obtained due to the use of oxalate.

If the preliminary treatment has been omitted, 101.3 c. c. of sample are measured out.

If desired, 200 c. c. portions of the sample may be titrated or the entire bottle may be taken. It is not believed, however, that any greater accuracy will result.

(*n*) Pour out the measured amount of sample into a 200 c. c. Erlenmeyer flask and titrate with N/40 thiosulphate until the amount of iodine remaining is about equivalent to 0.5 c. c. of N/40 thiosulphate. This is a pale straw color.

(*o*) Add 1 or 2 c. c. of freshly prepared starch solution and titrate to the disappearance of the blue color. The end-point should be obtained with 0.05 c. c. of N/40 thiosulphate without difficulty.

(*p*) Where several samples are being run at the same time, four of five flasks may be poured out at once if the titrations are made rapidly and promptly. The loss of iodine by diffusion into the air is appreciable if the oxygen content exceeds, say, 7 parts per million, and the titration is unduly delayed.

(*q*) If the amount titrated is equivalent to 100 c. c. of the original sample, the dissolved oxygen content in parts per million is twice the number of cubic centimeters of N/40 thiosulphate used.

11. *Biochemical oxygen demand.*—The excess oxygen method was used in all the determinations made. Since this method is not described in Standard Methods and is not in general use in this country, it will be given somewhat in detail. The method has been used extensively by the Public Health Service with good results. It has advantages of simulating natural conditions more closely than any other and the values derived are of fundamental importance. With suitable working arrangements the tests can be carried out rapidly and conveniently.

DEFINITIONS

The biochemical oxygen demand of a polluted water, a sewage or an industrial waste is defined as the milligrams of oxygen per liter required for the stabilization of its organic matter by aerobic bacterial action.

The initial oxygen demand is defined as the milligrams of oxygen per liter that may be taken up on dilution with aerated water by a sample devoid of oxygen even if the sample is sterile. This purely chemical part of the oxygen requirement may be due to the presence of easily oxidizable sulphides, ferrous salts, etc., and is generally satisfied during the first few hours of incubation. It represents the oxygen which would be required within a few hours after the discharge of a waste into a stream.

RATIONALE OF THE METHOD

The sample is incubated at 20° C. for a definite period of time. The dissolved oxygen content of the sample is determined before and after incubation, and the amount of oxygen used up is taken as a measure of the oxygen demand of the sample for the period of incubation used. If there is an appreciable initial oxygen demand it is determined and deducted from the total value to obtain the biochemical oxygen demand. If the sample is sterile it must be seeded with sewage bacteria. If it contains an insufficient amount of dissolved oxygen it must be diluted with water containing dissolved oxygen, in which case a correction must be made for the oxygen demand of the diluting water used.

APPARATUS, GLASSWARE

Carboys.—Twenty liter capacity, to store tap water for dilution purposes. Distilled water may be used without storage, if of suitable quality.

Incubation bottles.—Preferably of 250 to 300 c. c. capacity and provided with ground-glass stoppers.

Devices to provide for volume changes during incubation or for entrapping liberated oxygen.—If it is desired to use devices of this character, it will be found convenient to use "open tubes" as devised by H. W. Streeter at the Baltimore sewage laboratory and later improved by him in connection with the Ohio River Investigation by the United States Public Health Service. These tubes are 6 inches long, and should be of thick glass of at least one-fourth inch inside diameter, with the edges smoothed in a flame. They are fitted at the center with a piece of heavy rubber tubing one inch long, slipping snugly over the tube, and of such thickness as to completely close the neck of the bottle. This device acts practically as a one-hole rubber stopper and a piece of glass tubing. To insert, place the moistened tube in the bottle until the rubber touches the liquid, then, holding the index finger over the open end of the tube, depress same into position. This device is not recommended as essential for 20° C. work.

Dilution flasks.—Two are required, one of 1,000 c. c. and one of 500 c. c. capacity.

Siphons.—Two siphons are necessary, one for filling the dilution flasks (see Fig. 37) and a smaller one for filling the bottles from the flasks. The siphons are easily made from glass and rubber tubing.

Incubator.—This should be capable of regulation within one degree of 20° C. Where incubators are not available, the samples should be stored in the dark as near to 20° C. as possible and a record made of the temperature.

REAGENTS

As given for dissolved oxygen determination in Standard Methods of the American Public Health Association.

DILUTING WATER

It is essential that the diluting water should have the following characteristics at the time of use.

(*a*) Its 10-day biochemical oxygen demand should be less than 0.6 parts per million.

(*b*) It should not be supersaturated with dissolved oxygen; i. e., its dissolved oxygen content should be less than 9.0 parts per million.

(*c*) The temperature of the diluting water should be approximately 20° C., if devices to provide for volume changes during incubation are not used.

Water fulfilling the above requirements can be easily obtained by storing water at about 20° C. until its oxygen demand is suitably reduced. For Cincinnati tap water, with a 10-day oxygen demand of about 1.3 parts per million, a storage period of 7 to 8 days is sufficient.

During the survey it was impracticable to use stored tap water for dilution purposes and accordingly distilled water was used. The results obtained indicate that distilled water can be used if desired. Apart from the added expenses involved, the use of stored tap water, however, is probably to be preferred, since distilled water generally contains appreciable amounts of free ammonia and nitrites and, being presumably sterile and devoid of mineral salts, is not strictly a blank.

PRELIMINARY DETERMINATIONS WITH INDUSTRIAL WASTES

(*a*) If the sample is acid or possesses hydrate alkalinity, bacterial activity will be inhibited. Neutralize with $NaHCO_3$ or Na_2CO_3. If the diluting water has a high bicarbonate alkalinity, this may be sufficient to neutralize the acidity or hydrate alkalinity of the sample in the concentration incubated.

If the sample is acid or possesses hydrate alkalinity or has been boiled, it should be seeded with sewage bacteria before incubation.

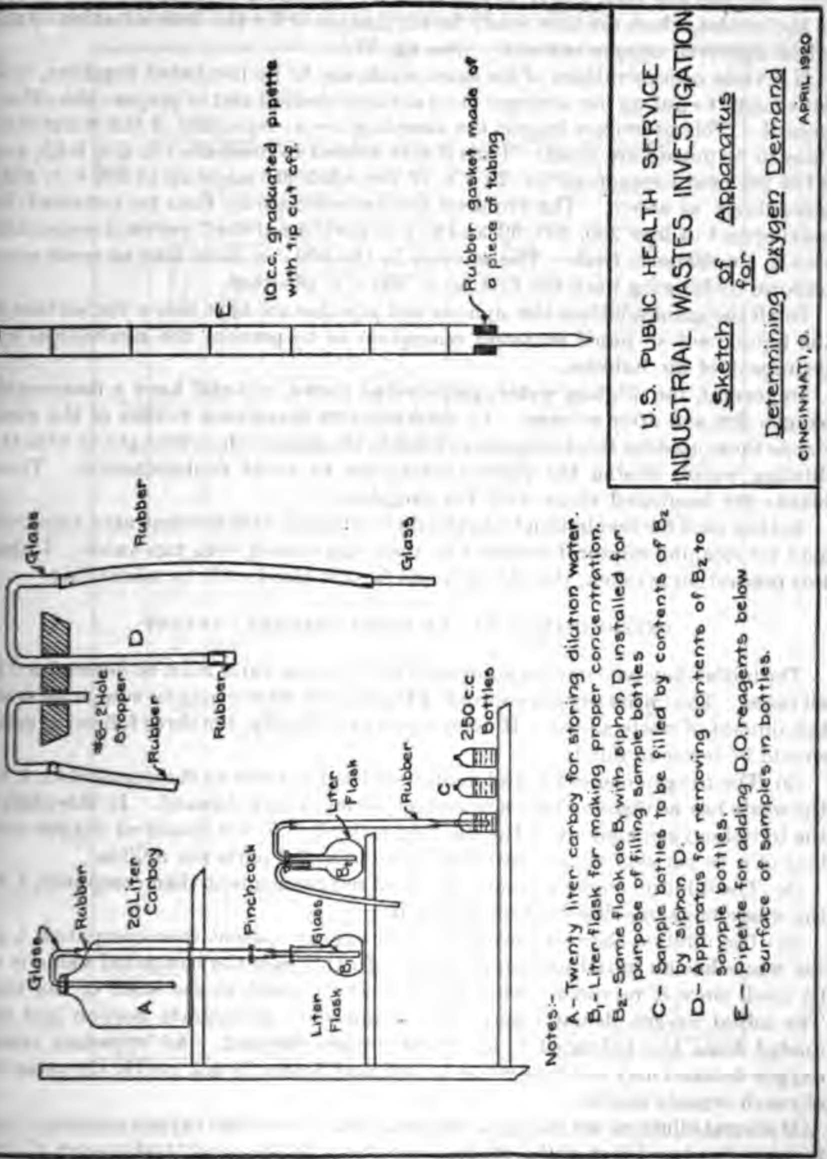
(*b*) The dissolved oxygen content of the sample is an index of its biochemical oxygen demand. If no oxygen is present, it indicates that the sample is heavily polluted; samples which have been heated or contain reducing chemicals are exceptions. Dissolved oxygen may also be present if the pollution is but recent. If the oxygen content is high the sample may be incubated without dilution, e. g., river water and effluents of good quality for short periods of incubation. If the sample contains over 9.0 parts per million of dissolved oxygen, "open tubes," as described above, may be used to trap any oxygen which might be liberated or, preferably, the excess of oxygen is removed by applying suction to a bottle partly filled with the sample. An apparent supersaturation may be obtained if nitrites are present and the Rideal modification is not used.

CHOICE OF CONCENTRATIONS TO BE INCUBATED

The concentration of waste incubated should be such that sizable depletions are obtained. If several concentrations are to be put up, they are made each 50 per cent of the next highest until the desired range has been compassed. The number of concentrations to be incubated will depend on the certainty with which the behavior of the sample is known and the duration of the incubation. For raw sewage, 5 and 2.5 per cent concentrations are suggested as trial amounts for 5-day periods of incubation. Final effluents of good quality may often be incubated without dilution.

METHODS OF PREPARING THE DILUTIONS

(*a*) Suitable amounts of the sample may be added directly to bottles of known apacity. This, however, complicates the computations and may introduce a


A
Glass
Rubber
20 Liter Carboy
Pinchcock
Glass
B_1
Liter Flask
B_2
Liter Flask
Rubber
C
250 c.c Bottles
Glass
#6-2 Hole Stopper
Rubber
Rubber
D
Rubber
Glass
Rubber
E
10 c.c. graduated pipette with tip cut off.
Rubber gasket made of a piece of tubing
U.S. PUBLIC HEALTH SERVICE
INDUSTRIAL WASTES INVESTIGATION
Sketch of Apparatus for Determining Oxygen Demand
CINCINNATI, O.
APRIL 1920

Notes:-
A - Twenty liter carboy for storing dilution water.
B_1 - Liter flask for making proper concentration.
B_2 - Same flask as B_1 with siphon D installed for purpose of filling sample bottles
C - Sample bottles to be filled by contents of B_2 by siphon D.
D - Apparatus for removing contents of B_2 to sample bottles.
E - Pipette for adding D.O. reagents below surface of samples in bottles.

FIG. 37

onsiderable sampling error if small amounts of samples are involved. The folwing procedure is recommended:

(*b*) A stock solution is prepared of the desired concentration and the incubation ottles are filled with it, using a siphon. Thus to prepare a 10 per cent concentraon, a liter flask is partly filled with the diluting water, 100 c. c. of the sample is added and the liter flask is filled to the mark with the diluting water, moving the siphon up and down to secure good mixing. The contents of the flask are then transferred to incubation bottles, using a small siphon, the first portion going over being rejected in order to clean out the siphon. The three bottles are first filled half full and then nearly to overflowing. Stoppers or tubes are then placed in the bottles, which are then ready for incubation or for the determination of the initial dissolved oxygen content. (See fig. 37.)

If several concentrations of the same waste are to be incubated together, it is convenient to put up one stronger than actually desired and to prepare the others from it. This procedure lessens the sampling error, especially if the concentrations to be put up are small. Thus if it is desired to incubate 1.0, 0.5, 0.25, and 0.125 per cent concentrations, 25 c. c. of the waste are made up to 500 c. c. with precautions as above. The required concentrations may then be obtained by making up to 1 liter 200, 100, 50, and 25 c. c. portions of the 5 per cent concentration in the 500 c. c. flask. The mixture in the 500 c. c. flask may be made more uniform by blowing back the first 50 or 100 c. c. pipetted.

In all the manipulations the siphons and pipettes are kept below the surface of the liquid, not so much to avoid reaeration as to prevent the mechanical entrainment of air bubbles.

In general, the diluting water, prepared as above, will still have a measurable oxygen demand after storage. To determine its magnitude bottles of the same size as those used for the dilutions are filled in the manner described above with the diluting water, rinsing the siphon before use to avoid contamination. These blanks are incubated along with the samples.

Bottles used for incubation tests should be cleaned with concentrated sulphuric acid (or cleaning mixture) followed by thorough rinsing with tap water. Unless this precaution is taken, the values found for the blanks will be misleading.

DETERMINATION OF THE INITIAL OXYGEN CONTENT

The initial dissolved oxygen content of the diluting water must be determined in all cases. The initial oxygen content of the diluted wastes may be computed from the amount of waste added. If determined analytically, the three following cases should be borne in mind:

(*a*) The oxygen content found analytically is the same as that computed, i. e., the waste has no dissolved oxygen and no initial oxygen demand. In this case, if the initial oxygen content of the diluting water is 8.0, the dissolved oxygen content of a 10 per cent concentration is, obviously, 7.2 parts per million.

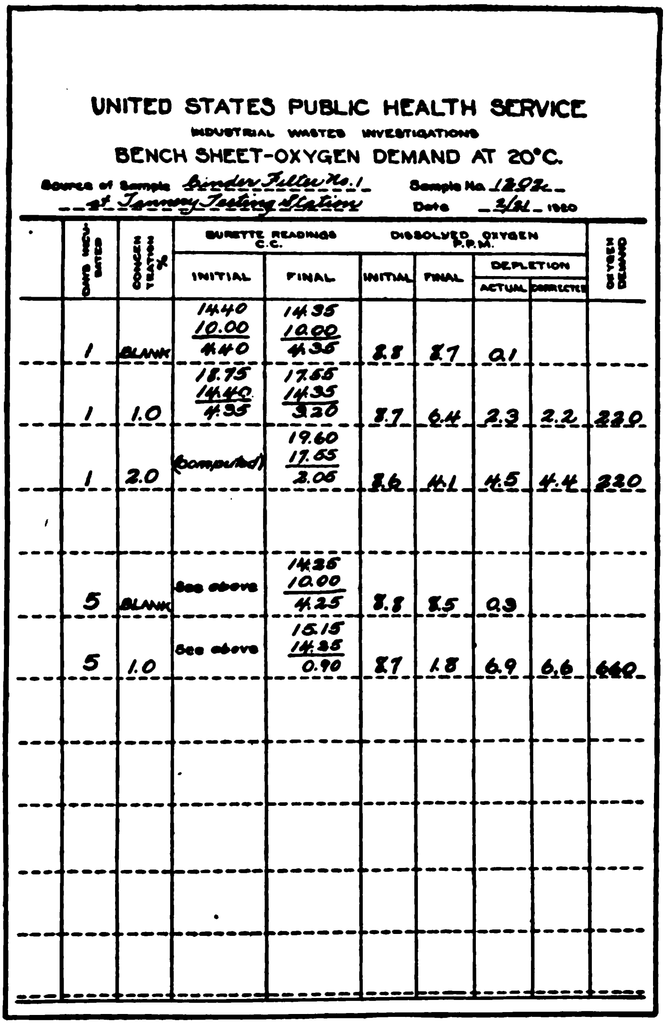
(*b*) The dilution shows a higher dissolved oxygen content than computed, i. e., the waste has some dissolved oxygen in it.

(*c*) The dilution shows a lower dissolved oxygen content than computed, i. e., the waste has an initial oxygen demand. In this case the computed value is to be used, since it represents what was actually present at the start of the test. The initial oxygen demand may be determined on a separate portion and deducted from the indicated biochemical oxygen demand. An apparent initial oxygen demand may be found if the Rideal modification is not used in the presence of much organic matter.

If several dilutions are put up at the same time, the initial oxygen content of one is determined and that of the others computed. If the concentrations are all less than 1 per cent, the value for the diluting water may be assumed as that for the diluted sample.

INITIAL OXYGEN DEMAND

The bottle chosen for this determination is allowed to stand for 10 minutes or longer until this purely chemical part of the reaction has been satisfied. Its oxygen content is then determined, using the Rideal modification. The following illustration will make the method of computing results clear:



UNITED STATES PUBLIC HEALTH SERVICE

INDUSTRIAL WASTES INVESTIGATIONS

BENCH SHEET-OXYGEN DEMAND AT 20°C.

Source of Sample Binder Filter No. 1 at Tannery Testing Station

Sample No. 1292

Date 2/21 1920

	DAYS INCUBATED	CONCENTRATION %	BURETTE READINGS C.C.		DISSOLVED OXYGEN P.P.M.				OXYGEN DEMAND
			INITIAL	FINAL	INITIAL	FINAL	DEPLETION		
							ACTUAL	CORRECTED	
	1	BLANK	14.40 10.00 4.40	14.35 10.00 4.35	8.8	8.7	0.1		
	1	1.0	18.75 14.40 4.35	17.55 14.35 3.20	8.7	6.4	2.3	2.2	220
	1	2.0	(computed)	19.60 17.65 2.05	8.6	4.1	4.5	4.4	220
	5	BLANK	See above	14.25 10.00 4.25	8.8	8.5	0.3		
	5	1.0	See above	15.15 14.25 0.90	8.7	1.8	6.9	6.6	660

FIG. 38

	P. p. m.
Initial dissolved oxygen content of the diluting water	8.0
Computed initial oxygen content of a 10 per cent concentration	7.2
Oxygen content found analytically	6.6
Initial oxygen demand of a 10 per cent concentration	0.6
Initial oxygen demand of the waste is	6.0

In most cases the initial oxygen demand is negligible in comparison with the 5 or 10 day demand and may be disregarded. It may, however, form a considerable portion of the 1-day demand.

PERIOD OF INCUBATION TO BE CHOSEN

A 10-day incubation period is taken as a practical limit for the duration of a test. The 10-day oxygen demand is 90 per cent of the 20-day or ultimate oxygen demand. It has been shown, however, that the period of incubation in most cases may be restricted to five days without any great sacrifice in accuracy, and this is the period recommended. To obtain the 10-day oxygen demand, the 5-day value is multiplied by 1.33, or the value found is simply reported as the 5-day oxygen demand. The 1-day oxygen demand value is not representative and may be misleading. The reader is referred to the Public Health Reports, May 7, 1920, for a discussion of the relations existing between oxygen demand values over different periods of incubation.

COMPUTATIONS

Given the initial and final oxygen content of a diluted sample over any period of time, the oxygen demand of the sample over that time is the corrected difference times a factor for the concentration used. The concentration factor is the reciprocal of the concentration when expressed decimally. Thus, for a 5 per cent concentration, or decimally expressed 0.05, the factor is 20.

The correction is based on the fact that the diluting water itself generally has an appreciable oxygen demand, and is determined by incubating the water under the same conditions as the diluted sample. The correction should be calculated for the amount of diluting water present. If the concentration is 50 per cent, the correction applied should be one-half the value found for the diluting water. If the concentrations are less than 10 per cent, the correction is considered equal to the biochemical oxygen demand of the diluting water and the same for all concentrations. The bench sheet (fig. 38) will make clear the method of computing oxygen demand values from analytical results.

The above directions have been compiled from methods in use by the Public Health Service and from material contained in Public Health Reprint No. 594. Copies of the reprint may be obtained from the Superintendent of Documents, Washington, D. C., and the reader is referred to this publication for further information.

12. *Sludge analyses.*—The procedures given in Standard Methods were followed quite closely. In view of the possible importance of sludge as a fertilizer, rather complete analyses were made of the sludge ash.

RELATED PUBLICATIONS

The following publications on sewage disposal, issued by the Public Health Service, may be obtained without cost so long as the supply lasts. The asterisk (*) indicates that the stock has been exhausted, but the publications so marked may be bought from the Superintendent of Documents, Washington, D. C.

PUBLIC HEALTH BULLETINS

No. 97. Studies on the treatment and disposal of industrial wastes: I. The reatment and disposal of strawboard waste, by Harry B. Hommon. II. The determination of biochemical oxygen demand of industrial wastes and sewage, by Emery J. Theriault and Harry B. Hommon. 1918.

No. 100. Studies on the treatment and disposal of industrial wastes: III. The purification of tannery wastes, by Harry B. Hommon. (Final Report. See Public Health Bulletin No. 97.) 1919.

* No. 107. Municipal wastes; their character, collection, and disposal, by H. R. Crohurst. 1910.

* No. 109. Studies on the treatment and disposal of industrial wastes: IV. The purification of creamery wastes, by Harry B. Hommon. 1921. 10 cents.

No. 118. Studies on the treatment and disposal of industrial wastes: V. The purification of tomato-canning wastes, by Harry B. Hommon. 1921.

REPRINTS FROM PUBLIC HEALTH REPORTS

No. 168. The water supplies of ships. Water for drinking and method of ewage disposal on ships on inland waters, by Hugh de Valin. February 13, 1914.

* No. 504. The treatment of sewage from single houses and small communities, by Earle B. Phelps. February 14, 1919. 5 cents.

No. 594. A further study of the excess oxygen method for the determination f the biochemical oxygen demand of sewages and industrial wastes, by E. J. Theriault. May 7, 1920. The determination of the biochemical oxygen demand f sewages and industrial wastes, by E. J. Theriault and H. B. Hommon. October, 1918.

No. 625. Sanitary disposal of sewage through a septic tank. Simple construcion and inexpensive operation for isolated dwellings, by H. R. Crohurst. December 0, 1920.

No. 761. Conclusions drawn from a survey of sewage treatment plants, by H. H. Wagenhals. June 23, 1922.

TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 133
MAY, 1923

TRANSACTIONS OF THE THIRD ANNUAL CONFERENCE OF STATE SANITARY ENGINEERS

HELD AT WASHINGTON, D. C.
MAY 17 and 18, 1922

PREPARED BY DIRECTION OF THE SURGEON GENERAL

WASHINGTON
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ashington	C. E. Dorisy	State sanitary engineer, division of sanitary engineering, State department of health.	Seattle.
est Virginia	E. S. Tisdale	Director, division of sanitary engineering, State department of health.	Charleston.
isconsin	C. M. Baker	State sanitary engineer, bureau of sanitary engineering, State board of health.	Madison.

UNITED STATES PUBLIC HEALTH SERVICE REPRESENTATIVES.

. M. **Fisher**, associate sanitary engineer, United States Public Health Service, 1243 Main Street, Columbia, S. C.

ol **Pincus**, associate sanitary engineer, United States Public Health Service, room 116, Customhouse, New York, N. Y.

. E. **Tarbett**, sanitary engineer, United States Public Health Service, Third and Kilgour Streets, Cincinnati, Ohio.

STANDING COMMITTEES.

WATER SUPPLY AND WATER PURIFICATION.

W. H. Dittoe, *Chairman.*

Abel Wolman.
C. A. Emerson, jr.
A. H. Jewell.
Theodore Horton.

SEWAGE AND STREAM POLLUTION.

R. E. Tarbett, *Chairman.*

V. M. Ehlers.
H. E. Miller.
G. H. Hazlehurst.
E. S. Tisdale.

MILK SUPPLY.

C. A. Emerson, jr., *Chairman.*

H. A. Whittaker.
C. M. Baker.
R. Hilscher.
C. A. Holmquist.

LAWS, ORGANIZATION, POLICY, AND PROCEDURE.

H. A. Whittaker, *Chairman.*

E. L. Filby.
J. H. O'Neill.
E. D. Rich.

MOSQUITO CONTROL.

G. W. Simons, jr., *Chairman.*

C. N. Harrub.
H. C. Woodfall.
L. M. Fisher.
M. Z. Bair.

BATHING BEACHES.

Stephen De M. Gage, *Chairman.*

G. W. Simons, jr.
R. Hilscher.
H. F. Ferguson.
E. S. Tisdale.

CONTROL AND LIMITATION OF CHLORINATION.

Abel Wolman, *Chairman.*

M. Z. Bair.
Sol Pincus.
A. H. Wieters.

EXECUTIVE COMMITTEE.

C. A. Emerson, jr., *Chairman.*

H. F. Ferguson.
Theodore Horton.
J. F. Jackson.
W. H. Dittoe.

PROVISIONAL PROGRAM.

WEDNESDAY, MAY 17.

MORNING SESSION, 9.30 A. M.

Registration, preliminary announcements, minutes of previous meetings, report of executive committee, unfinished business.

Report of committee on laws, organization, policy, and procedure.

Open discussion on certification policy for water supplied to common carriers.

Report of committee on bathing places.

AFTERNOON SESSION, 2 P. M.

Report of committee on water supply and water purification.

Report of committee on control and limitation of chlorination.

Report of committee on milk supply.

Report of committee on sewage and stream pollution.

Remarks on Imhoff tank patents: William F. Keohan, Washington representative of the Chemical Foundation (Inc.).

THURSDAY, MAY 18.

MORNING SESSION, 9 A. M.

Electrolytic production of chlorine with special reference to water treatment: Clarence Marsh, New York City.

Conduct of educational campaigns for better water supplies: E. S. Tisdale, West Virginia.

Open forum discussion of State sanitary engineering matters.

Reports of special committees.

Election of officers.

THIRD ANNUAL CONFERENCE OF STATE SANITARY ENGINEERS.

TRANSACTIONS.

Morning Session, Wednesday, May 17, 1922.

The Third Annual Conference of State Sanitary Engineers was called to order by Chairman Emerson in room 2144, Department of the Interior Building, Washington, D. C., at 9.45 a. m., standard time, on May 17, 1922. The roll call showed the following to be present:

MEMBERS.

Arkansas	M. Z. Bair.
Connecticut	J. Frederick Jackson.
Florida	George W. Simons.
Illinois	Harry F. Ferguson.
ndiana	L. A. Geupel.
owa	Hans V. Pedersen.
Kentucky	F. C. Dugan.
Minnesota	H. A. Whittaker.
New York	Charles A. Holmquist. Theodore Horton.
North Carolina	H. E. Miller.
Ohio	W. H. Dittoe.
Pennsylavania	C. A. Emerson.
Rhode Island	Stephen De M. Gage.
South Carolina	E. L. Filby.
Tennessee	C. N. Harrub.
Texas	V. M. Ehlers.
Washington	C. E. Dorisy.
West Virginia	Ellis S. Tisdale.
U. S. P. H. S	L. M. Fisher.
U. S. P. H. S	Sol Pincus.
U. S. P. H. S	H. W. Streeter (representing R. E. Tarbett).
Corresponding secretary	I. W. Mendelsohn.

VISITORS.

A. J. McLaughlin, assistant surgeon general, United States Public Health Service.
W. H. Frost, surgeon, United States Public Health Service.
R. R. Sayers, passed assistant surgeon, United States Public Health Service.
. W. Tay, sanitary engineer, Hawaii Territorial Board of Health.
William F. Keohan, Chemical Foundation (Inc.).
. Fischer Miller, Pacific Flush Tank Co.
Clarence W. Marsh, consulting engineer.
Edward B. Besselievre, consulting engineer.

Mr. Emerson presented the views of the executive committee regarding membership in the conference. A motion was made by Mr. Harrub, seconded and carried, that no State be eligible for membership in the Conference of State Sanitary Engineers until a State sanitary engineering division had been established.

REPORT OF THE CORRESPONDING SECRETARY OF THE CONFERENCE OF STATE SANITARY ENGINEERS, MAY 17, 1922.

As brought out in the report in 1921, the transmission of information to State sanitary engineers concerning their technical activities was continued during the past year. State sanitary engineers were assisted in obtaining information regarding special technical problems in garbage disposal, camp sanitation, etc., on various occasions. Through the Public Health Engineering Abstracts articles of interest were brought to the attention of the State sanitary engineers. This service has been improved by increasing the number of abstractors, who at present are Associate Sanitary Engineer A. F. Allen, Dr. H. R. Carter, Assistant Sanitary Engineer J. I. Connolly, Junior Assistant Sanitary Engineer A. L. Dopmeyer, Associate Sanitary Engineer L. M. Fisher, Assistant Sanitary Engineer A. E. Gorman, Sanitary Engineer W. E. Hardenburgh, Mr. Frank Hannan, Sanitary Engineer H. B. Hommon, Junior Assistant Sanitary Engineer L. D. Mars, Assistant Sanitary Engineer I. W. Mendelsohn, Junior Assistant Sanitary Engineer A. P. Miller, Associate Sanitary Engineer Sol Pincus, Junior Assistant Sanitary Engineer E. C. Sullivan, Assistant Chemist E. J. Theriault, Mr. R. E. Thompson, Associate Sanitary Engineer H. H. Wagenhals, and Mr. Abel Wolman.

It is intended to issue an index for the 1921 abstracts within the next few weeks.

The transactions of the Conference of State Sanitary Engineers for the 1920 meeting have already been printed and copies of the transactions of the 1921 meeting will soon be available.

Mr. H. A. Whittaker, director, division of sanitation, Minnesota State Board of Health, then read the report of the committee on laws, organization, policy, and procedure.

REPORT OF COMMITTEE ON LAWS, ORGANIZATION, POLICY, AND PROCEDURE.

The committee has collected certain information from State boards and departments of health in the United States concerning the subdivisions of their organization which include in their activities sanitary engineering problems. This information was collected primarily for the purpose of assembling data on the existing facilities for carrying on sanitary engineering work in the several States. A questionnaire was prepared and sent to the States, which in general requested the following information: The name of the subdivision handling the sanitary engineering problems; the date and authority for its establishment; its duties, funds, personnel, laboratory facilities, and laws and regulations requiring approval of plans on sanitary works. Information was also requested on the work accomplished by each State along sanitary engineering lines and the extent of the work available. It was thought that this information might be of value in determining the need for extending sanitary engineering activities in States where inadequate facilities were provided. The material received in reply to this question was so indefinite in most instances that the committee decided it could not be correlated in such a form that any satisfactory data could be obtained from it.

Material was supplied by 38 States, of which 31 have subdivisions in their organization handling sanitary engineering problems. Of the seven States having no separately organized subdivision for this work, two, namely, Missouri and Oregon, are assisted by sanitary engineers of the United States Public Health Service; two States, namely, South Carolina and North Dakota, have State sanitary engineers who undertake certain work on water supplies and sewerage systems. The State of South Carolina is also undertaking work on malaria control in cooperation with the United States Public Health Service. The State of Arizona receives a small appropriation for rural sanitation which is expended under the direction of the State superintendent of health. The department of public welfare of the State of Idaho undertakes certain examinations of water supplies, milk supplies, and investigations of sewage disposal. The State of Wyoming reports that no work is undertaken along sanitary engineering lines.

DESIGNATION OF DIVISION, DATE, AND AUTHORITY FOR ESTABLISHMENT.

There is a variety of names used to designate the subdivision of health work undertaking sanitary engineering problems. Of the 31 States having this branch of health work, 11, namely, the States of Alabama, California, Connecticut, Florida, Kentucky, Louisiana, Maryland, Mississippi, Tennessee, Texas, and Wisconsin, use the designation "Bureau of sanitary engineering"; the following States use the designation "Division of sanitary engineering": Arkansas, Massachusetts, Nebraska, New York, Ohio, Pennsylvania, Washington, and West Virginia. The States of Kansas and Montana use the title of "Division of water and sewage." The remaining 10 States use titles as follows: Michigan, "Bureau of engineering"; North Carolina, "Bureau of sanitary engineering and inspection"; Minnesota, "Division of sanitation"; Georgia, "Division of sanitary engineering and water analysis"; Illinois, "Division of engineering and sanitation"; New Mexico, "Division of sanitary engineering and sanitation"; Rhode Island, "Division of chemistry and sanitary engineering"; Indiana, "Division of chemistry, water and sewage department"; Virginia, "Sanitary engineering division"; and New Hampshire, "Chemical department, State laboratory of hygiene."

All of these subdivisions, in their present form of organization, have been established since 1897; about 14 per cent prior to 1910 and 86 per cent since that time. It should be understood that some of these States have been doing work on sanitary engineering problems for many years prior to the date indicated, but under a different form of organization. This indicates the comparatively recent recognition of the necessity for a separate subdivision of this kind in public health organizations. Thirteen States reported that their subdivisions were created by board or department action, 15 by State law or act, and in 3 cases no information was provided as to what legal authority governed their establishment.

DUTIES.

A wide range of duties have been assigned by the various States to this subdivision of health work. An enumeration of the duties reported include the following general subjects: Water supplies, milk supplies, ice supplies, sewerage systems and sewage disposal, stream pollution, shellfish, trade-waste disposal, plumbing, garbage and refuse disposal, nuisances, offensive trades, abattoirs, building sanitation, housing, rat-proofing, fly eradication, swimming pools and bathing beaches, rural sanitation, and epidemics (milk and waterborne).

FUNDS AVAILABLE.

Of the 31 States handling sanitary engineering problems under a separate subdivision, 23 reported that definite appropriations were made to carry on this work. In some instances the total funds were not all appropriated directly for sanitary engineering, but were partly obtained from other funds of the board or department of health or from fees for sanitary engineering or laboratory work connected with sanitary engineering problems. Seven States reporting receive no direct appropriation for this work, but carry on their activities from other funds of their boards or departments of health. One State derives its resources from a State tax on privies; no information was given as to the amount received.

PERSONNEL.

The information supplied concerning the personnel having charge of sanitary engineering problems in the 35 States reporting activities along these lines indicates that there is very little uniformity in the classification of personnel engaged in this branch of health work. The titles of positions given to those in charge of the work in the various States are as follows: State sanitary engineer, chief engineer, chief sanitary engineer, and director or chief of bureau, division, or department. The salaries paid these positions range from $2,400 to $7,000 per annum. Other personnel attached to this branch of health work are assistant engineers (all grades), with salaries ranging from $1,800 to $3,450; engineering assistants, with salaries ranging from $1,200 to $2,000; inspectors, salaries ranging from $1,500 to $2,500; draftsmen, $1,500 to $1,800; chemists, $1,200 to $1,800; assistant chemists, $720 to $1,800; bacteriologists, $1,200 to $3,000; assistant bacteriologists, $900 to $1,500; laboratory assistants, $900 to $2,400; and analysts and technicians, $960 to $2,700.

LABORATORY FACILITIES AND RESPONSIBILITY FOR LABORATORY WORK.

Information provided in reply to the inquiry as to whether the laboratory work covering sanitary engineering problems is under the direct supervision of the sanitary engineering subdivision of the State board or department of health, or under supervision of some other subdivision, indicates that 13 of the 33 States reporting on this question have laboratory work on sanitary engineering problems supervised by sanitary engineers or sanitary engineering subdivisions. In one State the sewage and industrial wastes laboratory is under direct supervision of the bureau of sanitary engineering while the water work is done in the general laboratory of the board. In 19 States where the sanitary engineering laboratory work is under the supervision of a laboratory division, the results are interpreted in 12 States by the sanitary engineering division or the sanitary engineer; in 2 States the results on public supplies are interpreted by the sanitary engineering division, and private supplies by the laboratory; and in 2 States the results are interpreted both by engineering and laboratory divisions. Eighteen States reported that they are making analytical examinations of samples of water on supplies where no field investigation has been made to determine the condition of the supply. Two States reported making analytical examinations on private supplies only where no field investigations had been made. The principal reasons given why some of the present methods of conducting laboratory work are not satisfactory are lack of equipment and personnel, and the lack of correlation and cooperation of work between laboratory and sanitary engineering divisions.

LAWS AND REGULATIONS REQUIRING APPROVAL OF PLANS ON SANITARY WORKS.

The following States have laws requiring the approval of plans on water and sewerage systems: Connecticut, Kansas, Massachusetts, Maryland, Michigan, New Hampshire, North Carolina, Ohio, Pennsylvania, West Virginia, and Wisconsin. The States of Alabama and Virginia require the approval of plans on water-supply systems only. The public health law of New York requires the approval of plans for all systems of sewerage and sewage disposal, for water and sewage disposal installations and systems for State institutions, and for plans for mosquito extermination work. The following States require the approval of plans on water-supply and sewerage systems by regulations of their boards or departments of health: Arkansas, Georgia, Illinois, Kentucky, Louisiana, Minnesota, Mississippi, Montana, Nebraska, New Mexico, and Tennessee. The State laws of Maryland and Wisconsin require the approval of plans on refuse disposal works. Regulations of the State Board of Health of Minnesota require the approval of plans on refuse disposal works and milk pasteurization plants.

CONCLUSION.

It is apparent that there is a growing appreciation of the need for a subdivision of work in the various State boards and departments of health for handling sanitary engineering problems. This is evidenced by the number of subdivisions which have been created recently in the various health organizations throughout the country.

A review of the data contained in this report indicates that there is very little uniformity in the organizations of State boards and departments in regard to their subdivisions handling sanitary engineering problems; this lack of uniformity was apparent in practically every phase of information assembled in this report. This is undoubtedly due to the great variety of conditions under which this branch of health work has been established in each State. It was the original intention of the committee to make further studies on the organization of subdivisions for handling sanitary engineering problems in State boards or departments of health with the view of suggesting a scheme of organization for this branch of health work, but after giving the matter careful consideration the committee has decided that it can best serve the immediate needs of the conference by undertaking each year a detailed study of specific problems on laws, organization, policy, or procedure rather than to consider at this time the general problem of organization.

A motion made by Mr. Ferguson was seconded and carried that this report be accepted by the conference.

A motion was made, seconded, and carried that the corresponding secretary collect data from each sanitary engineering division as to salaries of employees at present and transmit such information to the members of the conference.

It was decided that copies of complete committee reports should be furnished the corresponding secretary by the chairmen, and that inquiries or questionnaires concerning the work of State sanitary engineering divisions should be referred to the corresponding secretary for reply.

Doctor McLaughlin spoke on the cooperative certification procedure for interstate carrier waters, remarking on the very favorable results obtained under the present policy.

Mr. W. H. Dittoe, chief division of sanitary engineering, Ohio State Department of Health, then read the report of the committee on water supply and water purification in which certain administrative modifications in the present cooperative certification procedure were considered.

REPORT OF COMMITTEE ON WATER SUPPLY AND WATER PURIFICATION.

Under date of March 10, 1922, Mr. C. A. Emerson, jr., chairman of the executive committee of the Conference of State Sanitary Engineers, referred to the committee on water supply and water purification a communication from Dr. C. C. Pierce, acting surgeon general, United States Public Health Service, dated March 4, 1922. This communication requests consideration by the Conference of State Sanitary Engineers of the proposed amendment to section 28 of the interstate quarantine regulations by the addition of the following paragraph:

> (*b*) Toilet wastes, water ballast, and other polluting material shall not be discharged from any vessel while it is in the vicinity of waterworks intakes used for public water supplies. The State health authorities having jurisdiction shall delimit the areas surrounding intakes which shall be protected against such pollution and shall notify the managing officers of the shipping companies concerned thereof.

The communication also requests consideration by the Conference of State Sanitary Engineers of the present cooperative certification procedure concerning water supplies used by common carriers in interstate traffic, and that the conference make such recommendations as may be deemed advisable in order to improve the procedure and make it more effective.

The following report of the committee on water supply and water purification is submitted pursuant to the above reference;

PREVIOUS COMMITTEE REPORTS.

At the meeting of the Conference of State Sanitary Engineers held June 1 and 2, 1921, a report was submitted by the committee on certification procedure. This report contained recommendations which were adopted by the Conference of State Sanitary Engineers.

At the Conference of State and Territorial Health Authorities June 3 and 4, 1921, the committee on certification policy submitted a report containing recommendations of modification in procedure. This report was adopted by the conference and the recommendations were subsequently carried out in the preparation of instructions issued by the United States Public Health Service concerning the certification of water supplies.

PROPOSED AMENDMENT TO SECTION 28, INTERSTATE QUARANTINE REGULATIONS.

This committee recognizes the necessity of preventing the discharge of sewage from vessels at points in the vicinity of public water supply intakes and is of opinion that the proposed amendment should be indorsed.

This committee also suggests consideration of further amendments to section 28 which will provide for the use of water-tight storage containers for sewage on steam and electric railroad cars and on vessels. In making this suggestion this committee considers the following points of importance:

First. The uncertainty of the required extent of the zone of protection of the water supply. This is particularly a difficult question in the case of river supplies.

Second. Convenience of the traveler.

Third. The impracticability of wholly preventing sewage discharge by the method of locking toilet rooms.

Fourth. The condition of nuisance which exists generally at stations as a result of the spilling of sewage on station platforms and tracks.

CERTIFICATION PROCEDURE.

SCOPE OF INTERSTATE QUARANTINE REGULATIONS.

This committee considers it advisable to explain that in accordance with an opinion of the Solicitor of the Treasury Department of the United States, the scope of the Interstate Quarantine Regulations applying to water-supply certification is sufficiently broad to cover all passenger carriers in intrastate as well as interstate business and all freight carriers in interstate business.

SIGNING OF CERTIFICATES.

This committee considers it important to state that the indorsement by the State health department of certificates of examination of water should be the signature of the executive officer of the department. This renders the indorsement official which is not strictly the case if the chief of a division of the health department signs the certificate.

NOTIFICATION TO CARRIERS REGARDING USE AND DISCONTINUANCE OF USE OF A WATER SUPPLY.

Much misunderstanding has existed regarding this matter, and your committee desires to set forth the following principles of procedure:

First. When a favorable or unfavorable certificate of a water supply is indorsed by the State health department and transmitted to the Surgeon General notification to the carrier by the State health department is unnecessary. Such notification is to be given by the Surgeon General.

Second. When a water supply which has been certified is in use and an unforeseen circumstance arises rendering such water supply unsafe, the State health department should notify the Surgeon General by wire confirming such notification by letter in order that formal notification to the carrier of withdrawal of the certificate for such water supply can be issued by the Surgeon General.

Third. In case a water supply, which has previously been denied a certificate, is improved so as to permit certification, the State health department should notify all carriers to which such supply is available in order that they may submit to the Surgeon General request for certification of the supply as improved.

NUMBER OF WATER SUPPLIES INVOLVED.

This committee is impressed with the belief that the public carriers, particularly the railroads, request certification of many more individual sources of water supply than the conditions require. It appears likely that many sources proposed are used rarely, if ever. This results in greatly increasing the work necessary and as most State health departments are limited in personnel, the thoroughness of the control is affected. This committee suggests that the Surgeon General urge all public carriers to give careful consideration to the general supervision of their water-supply work with the object of limiting as much as possible the number of sources of water supplies used.

ICE.

Section 19, paragraph (d), of the Interstate Quarantine Regulations, provides that "water cooled for drinking purposes shall be cooled in such manner that ice can not come into contact with such water." The enforcement of this regulation requires improved coolers separating the ice from the water cooled. This regulation is in effect as regards new transportation equipment, but its enforcement is withheld until July 1, 1924, with regard to old equipment. Before that date new coolers are to be installed in all existing transportation equipment. In the meantime ice must be used in direct contact with water in such cases. There is no regulation requiring certification of ice. This committee is of opinion that a regulation should be made effective specifying that ice used in direct contact with water must be distilled water ice or natural or artificial ice of known purity and that such ice shall be handled in such manner that the safety or sanitary quality shall not be impaired.

TRANSPORTED WATER SUPPLIES.

In numerous cases carriers transported water from a certified source to a distant point where it is used for filling water coolers. This procedure should be avoided, if possible, owing to the danger of contaminating the water supply in handling. In some cases transportation is necessary, and this committee considers it advisable to offer explanation of procedure to be followed in such instances:

First. When the source of supply and the watering point are in the same State, the State health department should certify the source of supply used, and the certificate should indicate the location of the watering point or points to which the water is to be transported.

Second. When the source is in a different State from the watering point, the State health department having jurisdiction over the source should prepare the certificate in quadruplicate, sending two copies to the Surgeon General and one copy to the State health department having jurisdiction over the watering point.

HANDLING OF WATER.

While the Interstate Quarantine Regulations, section 19, paragraph (d), require carriers to cause water to be handled in a safe and sanitary manner, this feature is quite frequently neglected, the result being that water originally satisfactory may become contaminated in handling. In endeavoring to control the quality of water used in interstate traffic it is not sufficient to insure the safety of the water supply at the source, but every step from the source to the consumer must be carefully guarded. This committee is of opinion that this is one of the most important features connected with the supervision of water supplies for interstate carriers and recommends that the Interstate Quarantine Regulations in this respect be strictly enforced.

The conference indorsed the proposed amendment to section 28 of the Interstate Quarantine Regulations, which consisted of adding the following paragraph:

> (*b*) Toilet wastes, water ballast, and other polluting material shall not be discharged from any vessel while it is in the vicinity of waterworks intakes used for public water supplies. The State health authorities having jurisdiction shall delimit the areas surrounding intakes which shall be protected against such pollution and shall notify the managing officers of the shipping companies concerned thereof.

A motion was made, seconded, and carried that this report be accepted by the conference.

The conference then adjourned until the afternoon session (12 noon).

May 17, 1922, Afternoon Session.

After a trip in Arlington County, Va., to inspect the sanitary conditions, the conference was reconvened in the Arlington courthouse at 3 p. m., Mr. Emerson presiding.

Mr. Stephen De M. Gage, chemist and sanitary engineer, State Board of Health of Rhode Island, presented the report of the committee on bathing places.

REPORT OF THE COMMITTEE ON BATHING PLACES.

The four members of your committee are also all members of a similar committee of the sanitary engineering section of the American Public Health Association. Mr. E. S. Tisdale, of West Virginia, who is also a member of the American Public Health Association committee, at our request has served as an associate member of our committee. These two committees have been able to work together as a single body and to pursue a regular and systematic sequence of investigations without unnecessary duplication of effort. We would suggest to the conference that Mr. Tisdale be added to your committee, thus making the committees of the two organizations identical in personnel.

LIQUID CHLORINE FOR POOL DISINFECTION.

Through the courtesy of the Wallace & Tiernan Co. a list of swimming pools using liquid chlorine was obtained and information from these various pools was requested. Replies were received from 44 pools located in 20 States and the District of Columbia.

Twenty-seven of the pools were able to report on their dosage. Seventeen pools did not know how much chlorine they were using or whether they were using any excess or not. All of the 44 pools reporting stated that bacterial analyses were made of their pool waters at intervals, but only a few of the pools stated that they attempted to control the chlorine dosage by analytical means. The known chlorine dosage varied from a minimum of 0.4 pound to a maximum of 20 pounds per million gallons, the average dosage being 6.6 pounds and the median about 6 pounds per million gallons.

Eleven (25 per cent) of the pools reported that an excess of chlorine was purposely added to the water. In only seven instances was the excess checked by analysis. In only two instances was a definite excess added. All others using an excess merely added a sufficient amount of chlorine to yield a positive reaction. At two pools the excess added was 0.4 and 0.6 p. p. m. chlorine.

At 17 (39 per cent) of the pools reporting the bathers have complained about the excess chlorine in the water. The nature of the various complaints were as follows:

	Pools.
Itching or irritation of skin	3
Disagreeable odor	5
Bad taste	1
Irritation of eyes	1

From various sources we have attempted to obtain opinions as to the amount of excess chlorine needed in swimming pool waters to obtain safety from the transmission of disease and at the same time safeguard against irritation of the eyes, and other mucous surfaces. The consensus of opinion among many water supply and health officials seems to be that for safety against disease transmission at least 0.5 p. p. m. excess chlorine should be held in the water at all times when there is any appreciable bathing load. As to how much chlorine can be used without causing irritation of the eyes, we have been able to obtain no definite information. Judging from the reports quoted previously, however, a much smaller amount of chlorine can be used than would be required to insure absolute safety against disease transmission. It would seem to your committee that this is a point of very great importance and that efforts should be made by health officials in various parts of the country to watch chlorine dosage not only of liquid chlorine dosed pools but also pools dosed with hypochlorite of lime in order that we may obtain more accurate information as to the limits of chlorine necessary and usable.

EPIDEMICS TRACEABLE TO BATHING PLACES.

During 1921 questionnaires were sent to all ear, eye, nose, and throat specialists in the United States and to a large proportion of the dermatologists requesting information as to their experience with patients who had apparently acquired disease from swimming pools or other bathing places, either from the water or from suits and towels.

Approximately 700 replies to this questionnaire have been received from 41 States and the Territory of Hawaii. A preliminary report embodying a part of the information obtained through these questionnaires from 627 physicians was presented at the New York meeting of the American Public Health Association and was published in the February number of the journal.

The most significant feature of the replies received and tabulated in that report was the fact that a large number of diseases of the ears, nose, throat, and skin were attributed to swimming pools or other bathing places as the mode of infection. A number of physicians reported epidemics of certain of these diseases, whose transmission through the medium of bathing places had been unsuspected by your committee.

Since publication of that report your committee have received communications asking that further information be given out as to the data upon which they based their report. Certain persons seem to feel that these diseases, or at least some of them, could not be transmitted in such manner. A retabulation of all the replies is now in progress, but the amount of work involved is so great that it has not been possible to present all of these various data at this time.

Your committee are thoroughly in accord with the belief that single reports of cases of any disease attributed to swimming pools or to any other source do not constitute proper evidence that such disease was transmitted through that means. When a considerable proportion of physicians specializing in certain subjects have taken the pains to search their records and to report to the committee the cases which have come to their attention which are directly attributable to infection through bathing water or through suits and towels used at bathing places, and when evidence of this nature has been reported by a considerable number of physicians from practically every part of the United States, we feel that the great mass of circumstantial evidence is sufficient. To this must be added the direct evidence of epidemics reported by physicians and health officials which had not hitherto been made public.

At this time we present the definite information regarding epidemics attributable or traced to bathing places as compiled from the reports or personal letters received in answer to our questionnaire. As an appendix to this report we also give abstracts from a few of the replies which we have received to indicate the character of the data upon which our report is based.

Epidemics of mild and acute conjunctivitis—purulent or catarrhal—traced or attributed to bathing place waters, were reported by 19 physicians from 12 cities in 8 States, as follows: Sacramento, Calif.; Camp Johnston, South Jacksonville, Fla.; Bath, Me.; Portland, Me.; Boston, Mass.; Brooklyn, N. Y.; Rochester, N. Y.; New York City (4 reports); Pittsburgh, Pa.; Philadelphia, Pa. (5 reports); Lake Geneva, Wis.

Epidemics of furunculosis of the external auditory canal, otitis media, and other ear infections, traced or attributed to bathing place water were reported by 10 physicians from 11 cities in 9 States, as follows: Aurora, Ill.; La Salle, Ill.; Bowling Green, Ky.; Waterville, Me.; Baltimore, Md.; Princeton, Lawrenceville, and Trenton, N. J.; Niagara Falls, N. Y.; Pittsburgh, Pa.; Lake Geneva, Wis.; Charlotte, N. C.

Epidemics of colds, rhinitis, sinus infections, etc., traced or attributed to bathing-place waters were reported by four physicians from four different cities in as many States, as follows: La Salle, Ill.; Baltimore, Md.; Tulsa, Okla.; New York City.

Epidemics of tonsillitis, pharyngitis, laryngitis, etc., traced or attributed to bathing-place water were reported by four physicians from four cities in as many different States, as follows: Sacramento, Calif.; Portland, Me.; Albuquerque, N. Mex.; Pittsburgh, Pa.

Epidemics of skin infection—not including infections of the nose and external ear which are included above—were reported by eight physicians from five cities located in four different States. Of these two epidemics of impetigo contageosa and one of boils—unclassified—were attributed to infected water; two epidemics of molluscum contageosum, one of tinea cruris, and one of pus infection—probably streptococcus type—were traced or attributed to infection through suits or towels. These epidemics were located as follows: Bridgeport, Conn. (water); Cape May, N. J. (water); Philadelphia, Pa. (three suits and towels, one water); Milwaukee, Wis. (suits and towels); Lake Geneva, Wis (water).

An epidemic of typhoid fever traced to a swimming pool at Louisville, Ky., was reported by a health officer from an adjacent State.

An epidemic of typhoid at a school camp definitely traced to bathing in a polluted stream was reported by health officials in Florida.

An intestinal epidemic traced to bathing in a polluted stream was reported by the health officer at Sante Fe, N. Mex.

It may be of interest to note also that an epidemic of catarrhal otitis following an outbreak of catarrhal conjunctivitis among bathers at the swimming pool at Freiburg, Germany, was reported by K. Amersbach in the Deut. Med. Wchnschr., August 4, 1921, and reviewed in the American Journal of Public Health, March, 1922.

STATE REGULATION OF BATHING PLACES.

So far as your committee have been able to obtain information, State regulations for the control of swimming pools and other bathing places have now been adopted in seven States: Arkansas, California, Florida, Idaho, Tennessee, Virginia, and West Virginia. Under the public health code of Ohio the State health department is also empowered "to establish, maintain, and regulate public baths and bathing houses," etc. A voluntary supervision over swimming pools and bathing beaches is also maintained by the State board of health in a few other States where statutory regulations have not been adopted. Abstracts of the regulations for the control of bathing places in the various States have just been published collectively in Volume IV of the Journal of the American Association for Promoting Hygiene and Public Baths.

ABSTRACTS FROM REPORTS OF EPIDEMICS TRACED OR ATTRIBUTED TO BATHING PLACES.

[Key: IENT—Eye, ear, nose, and throat specialist. D—Dermatologist. H. O.—Health official. Figures—Key number of reply.]

"I have been able to trace several epidemics of acute catarrhal conjunctivitis to public swimming pools." Pittsburgh, Pa., 87—I.

"Have seen three epidemics of acute contagious conjunctivitis (Koch-Weeks bacillus) traceable to public baths. In two cases salt water swimming pool, in one case fresh water." New York City, 223—IENT.

"A few years ago we had an epidemic of acute catarrhal conjunctivitis, beginning with opening of the pools and stopping after water was treated." Philadelphia, Pa., 148—I.

"Some years ago I had a group of cases of conjunctivitis under such conditions that I believe they originated in a municipal bathing pool. I have seen one or two cases of pyodermia originating from unsterilized bathing suits." Boston, Mass. 255—D.

"I have seen conjunctivitis and pharyngitis in quantities that amounted to small epidemics that could not be traced except through swimming pools." Portland, Me., 57—I.

"Have seen several small outbreaks of conjunctivitis and tonsillitis from pool waters." Sacramento, Calif., 706—H. O.

"Mild epidemic of tonsillitis and pharyngitis and cases of conjunctivitis at various times from water." Albuquerque, N. Mex., 790—EINT.

"Frequently frontal sinus involvement will become epidemic, all cases coming from one swimming pool. We have had three or four of these epidemics in the past three years. As many as 40 or 50 cases from Y. M. pool at one time." Tulsa, Okla., 793—IENT.

"Have seen frequent epidemic infections of upper air tract among bathers in a given pool." New York City, 338—IENT.

"During August a daily average of 10 to 20 cases in which a reliable history of bath infection is given, mostly rhinitis, sinusitis, otitis, etc." Baltimore, Md., 192—IENT.

"Had an epidemic of otitis media and furunculosis of external canal here last June and July from public bathing places in our neighborhood." Niagara Falls, N. Y., 142—EI.

"Many cases of aural furunculosis among patients from Princeton, Lawrenceville, and Trenton swimming pools and from Charlotte, N. C., during the war. I have no doubt the pools were the cause." Trenton, N. J., 113—IENT.

"This past summer I have had a large series of cases of otitis externa (furunculosis) from three different camps on different lakes. The large increase in cases this year leads me to feel that the water at these bathing places must have been the source of infection." Waterville, Me., 76—ENT.

"Have had numbers of cases of scabies, impetigo contagiosa, molluscum, contagiosum—nearly 100 cases at University of Pennsylvania gymnasium several years ago—from suits and towels." Cynroyd, Pa., 154—D.

"Had an epidemic of over 100 cases of mulluscum contagiosum, and about 50 cases tinea cruris from towels used in one of our large Philadelphia institutions." Philadelphia, Pa., 159—D.

"Impetigo contagiosa was epidemic along the beaches in the summer of 1920." Bridgeport, Conn., 100—D.

"Typhoid epidemic, Louisville, Ky., 1912, White City pool." Roseville, Ill., 802—H. O.

"Know of one crop of cases of typhoid and intestinal infections definitely traced to bathing in stream polluted by sewage from hospital containing typhoid patients."—Santa Fe, N. Mex., 745—H. O.

Mr. C. A. EMERSON, Jr.[1] The committee has started work on a subject which probably has a material public health significance. Certainly it is one of much importance in the mind of the bathers. Patronage of bathing places is apparently increasing all over the country. I feel our investigations should be continued so that if the matter is important from the public health standpoint we will have information necessary for rational corrective measures and if it is not a real and important public health question we will have justification for telling the public that the design and operation of such places is not of concern to the State health organization.

Mr. H. A. WHITTAKER. The Minnesota State Board of Health investigated the Lake Calhoun public baths in the city of Minneapolis in 1917. This investigation was made at the request of the Civic and Commerce Association for the reason that numerous complaints had been made by citizens to the effect that they had received disease from bathing in this beach. This investigation was conducted cooperatively by the division of sanitation and the division of preventable diseases.

A detailed survey was made by the division of sanitation on Lake Calhoun, the bath house, its equipment, and the operation of the bathing beach. This survey included bacteriological, chemical, and physical determinations on the water. Arrangements were made with the board of park commissioners to report immediately to the division of preventable disease any complaints regarding diseases which had been contracted at the bathing beach. This investigation covered a period from about the time the bathing beach was opened in the spring until it was closed in the fall. The results of the investigation by the division of sanitation showed that the pavilion at the bathing beach was operated in a satisfactory manner but that the water in the bathing area was highly polluted at certain times during the bathing periods. Recommendations were made for improving conditions in the bathing area.

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[1] All statements in discussions in this bulletin were prepared by the various speakers several weeks after the conference and do not contain the exact words of the speakers at the meeting.

The results of the investigation of the division of preventable diseases did not show any cases of sickness that could be attributed to this public bathing place. Inference was drawn from the results of this investigation that this bathing beach was not a factor in the transmission of communicable diseases. This should not be interpreted to mean that all bathing places are not a menace to health, but attention is drawn to the fact that information indicating a bathing place as a source of communicable diseases which is not based on careful epidemiological studies should not be accepted since it may lead to very erroneous conclusions.

A motion was made, seconded, and carried that the report be accepted by the conference.

A report by Mr. Robert B. Morse, chief engineer, Maryland State Department of Health, chairman of the committee on control and limitation of chlorination, was then presented by Mr. Pincus, associate sanitary engineer, United States Public Health Service.

REPORT OF THE COMMITTEE ON LIMITATION AND CONTROL OF CHLORINATION OF WATER.

LIMITATION OF CHLORINE APPLICATION.

It is commonly assumed in waterworks practice that chlorination, as a water purification process, is an irregular, haphazard treatment, little understood and poorly controlled. The origin of this assumption lies probably in the earlier conception of a constant chlorine dose as a "cure-all" for water supply ills of a bacterial nature. The failure of experience to confirm this conception of chlorination resulted in a swing of the mental pendulum to the attitude of perpetual suspicion.

An analysis of our attitude at various periods toward this process is fruitful if we are to formulate any logical policy toward its application. From such an analysis should emanate the primary conclusions upon which our report should rest. Obviously, if experience indicates that chlorination is of highly fluctuating efficiency and of uncertain reliability, in comparison with other known treatment methods, this evidence should influence the final decision as to its general and successful applicability to different waters.

What, then, does experience teach with reference to our problem? The lessons of experience must not be interpreted merely by the use of bare analytical data. They should be viewed in the light of progressive knowledge concerning the processes under study. If this procedure is carried out, we may view the history of chlorination as of several stages. The earliest stage was one of complete confidence in the process as a panacea, the second one of rising suspicion, and the third, unfamiliar as yet perhaps to some of us, one of restoration of confidence in chlorination as a mechanism of bacterial treatment at least on a parity with storage or filtration.

These three stages are easily explicable. In the first era, little evidence other than hypothesis, was available for judgment, with the result that our hopes ran high. As the process was applied indiscriminately to different kinds of water, with practically no attempt at sane study or logical control, failures began to appear, with a reversion of confidence in its wake. This period still laps over on our present stage in the case of many practitioners. Somewhere in this second period, the time differing in different places and not yet reached in far too many instances, an effort was made to learn something of the mechanism of chlorination and of the causes of some of the failures. In the course of these studies, followed by practical applications of their findings, it soon appeared that many, if not most, of chlorination failures were failures of understanding and not of process. At this time, therefore, evidence is accumulating daily from many directions to indicate that a new conception of chlorination may well be formulated.

A statement of this attitude is presented at this point, for upon it is based the policy of application recommended. Following its presentation, the committee sets forth some of the facts which led it to accept this concept, new or old, depending upon individual experience and upon one's orientation with new data before him.

Chlorination, as a water treatment process, is reliable, controllable, and effective. It is no less so, from a bacteriological standpoint. than filtration, for example, whose mechanism is no better understood, whose efficiency is no less variable, and whose operation is in general no simpler than that of chlorination. It is as unjust to condemn chlorination on the score that it fails when improperly controlled, either in application or in apparatus, as it is to deny the advantages of filtration, because sometimes filters are poorly operated. As a matter of fact, there are perhaps greater difficulties, mechanical, biological, and physical, encountered in filtration than in disinfection processes.

What is the basis for the conclusion of your committee that chlorination, as now conceived, is reliable, controllable, and effective? Likewise, what are the natures of the waters upon which these conclusions are based? If it is demonstrable that chlorination produces a manifestly good bacterial quality of water continuously upon waters ranging in turbidity below a maximum of five parts per million to one sometimes reaching over 75 parts per million, then it may be assumed that the process is reliable bacteriologically. For this reason, the following experience data are presented. In each of these instances, with one exception (D), the control of chlorination is based upon residual chlorine tests as later outlined. In the exception, the chlorine dose was probably high enough all the time and too high some of the time.

Analyses of chlorinated waters.

Plant.	Turbidity of water chlorinated, p. p. m. range.	Total samples.	*B. coli* per 100 c. c., number between—						Notes.
			0–2	3–5	6–10	11–15	16–20	21+	
A	0– 5	238	217	13	2	5	0	1	Presumptive.
B	0– 5	252	236	6	2	1	0	7	Isolation.
C	5–75	110	103	1	3	1	1	1	Do.
D	5–75	267	267	0	0	0	0	0	Do.
E	0–15	94	80	7	6	1	0	0	Presumptive.

These data, together with similar material reported in waterworks literature from Grand Rapids, Mich., New York City, and elsewhere, indicate the continuous bacterial efficiency of chlorination when properly controlled. Reference to the charts appearing in the report of a study carried out by Enslow on 16 plants in Virginia, demonstrate likewise that the limitations on chlorine application have been primarily those of control and not those inherent in the process. (Cf. Journal of the American Waterworks Association, September, 1922.)

If chlorine is continuously applied, in amounts determined upon as described later, satisfactory waters result, from the standpoint of bacterial content. Continuous application is possible if due provision is made for duplicate apparatus and for reserve supplies of chlorine. These latter details are problems of management and not of mechanism of process.

The lower limit of chlorination effectiveness is usually thought to be due to excessive turbidity of the water. The committee has not available any data from well-controlled experiments on turbid waters, which have been chlorinated with a proper application of chemical to meet increased demand, from which it can assume that it is impossible to obtain a continuously safe water by chlorination of a supply with turbidities above 100 p. p. m. The supposed protective effect of suspended material upon bacteria is, so far as we know, nothing more than an hypothesis, probably given some support in the past by analytical results, which may have had their origin as much in improper and discontinuous control of chlorine application as in "protective effect."

The committee prefers to suggest no limit upon the application of chlorine on the score that, (*a*) in raw waters, the limit is reached by æsthetic objection to a turbid or discolored water long before chlorination fails; (*b*) in filtered waters, good management presupposes the most effective use of all treatment processes regardless of additional aids, such as chlorination, which may be developed from time to time; and (*c*) in underground waters, the limits are set by sanitary survey and history of the water rather than by defects in the chemical process.

The position taken by the committee will bear further explanation. It hardly seems desirable to establish any limit of quality of raw water below which chlorine, by itself, should not be used. It is generally agreed that most surface waters, except perhaps those from sparsely inhabited and wooded watersheds, which are often subject to little pollution, should not be used without filtration. For this class, therefore, it is better to formulate a policy of filtration than one of maximum limit for chlorination. Here chlorination alone may serve as a temporary bacterial guard, but other considerations, æsthetic as well as sanitary, demand filtration as well as chemical disinfection. The general policy depends fundamentally, therefore, on questions entirely aside from the adequacy of the chlorination process.

In a similar manner, it is hardly necessary to establish a maximum allowable bacterial limit for filter effluents prior to chlorine treatment, if we establish as a working principle the theorem that each part of the filtration process should be operated at the maximum efficiency. In this case, our policy again is negative with respect to chlorination, but positive with reference to the processes which it accompanies. In these statements, we assume that chlorine is an integral part of the water treatment program, no more or less so than any other part thereof. Because chlorine meets good as well as bad effluents, it is no more of a hybrid than the filter unit whose very existence presupposes a variability in the water reaching it. If, in a filtration plant, each unit of treatment is operated to its maximum advantage, it is difficult to see what would be gained by establishing a standard quality for prechlorinated water, at least before one for precoagulated or prefiltered water is determined upon. When our knowledge of maximum loading of each process is much more complete, we may be in a position to define such standards. Even then it will be necessary to start at the beginning for each step in purification rather than at the end, where incidentally the fluctuating burden is frequently and easily carried by chlorine.

Before leaving the discussion of the treatment of filter effluents, some reference should be made to the question frequently raised as to whether chlorination should be viewed as an integral part of treatment or as a factor of safety. This question appears to the committee to be more of academic interest than of practical significance. It is generally conceded that no filter unit produces a water free from colon during each second of its operation. It is a fact also that there are many instances where filter effluents are relatively turbid for longer or shorter periods. Few plants, even the largest, upon rigid scrutiny of their operation, produce a water of zero turbidity. In other words, filter effluents, like raw waters, are continually in a state of change. This fact is often lost sight of in published data of average bacterial content of filtered water before chlorine treatment. An effluent, for example, which shows an average *B. coli* content of 1.5 per 100 c. c. is unsatisfactory without chlorine treatment, assuming the Treasury Department standard should be met every minute of operation, because this value of 1.5 of itself indicates that some of the water probably had considerably more than 1.5 per 100 c. c. in order to give such an average as above.

If we recognize as a fact the fluctuating character of filter effluents, both physical and bacterial, it is somewhat fruitless to quibble about the function of chlorination in the process. Incidentally this fluctuation in filter effluent quality is considerably greater than was formerly realized, when it is measured by the more refined methods of testing now available. Since it is impossible to predict, even with the best of supervision, the periods of deterioration of filter effluent quality, nothing remains but to use chlorine continuously.

Paradoxical as it may seem, chlorination is both a factor of safety and an integral part of water treatment when used in conjunction with filtration. We may call it a factor of safety because it meets unforeseen variations in effluents, but it remains an integral part of the process, for without it satisfactory results, on our present bases, are unobtainable continuously. The paradox is just as true in the case of filtration, for this process may be simply polishing off a clear raw water at times, while at others it must take care of highly polluted or turbid applied waters. Just because filtration meets the state of change in an applied water, it does not have to be assigned to the class either of "factor of safety" or "integral part." The true function of a "factor of safety" in engineering practice is its provision for the unknown or unexpected contingencies. In this sense, all of our treatment processes become at one time or another factors of safety, but retain their claim as integral parts of the whole series of mechanisms. There appears to be no reason why chlorination should be singled out as a test case for the determination of a classification in treatment, which after all may be a mere question of nomenclature or of language. The position taken by the committee may be made clearer by an example. If, for certain considerations of power, a six-cylinder engine is substituted for a four, and this new machine, through poor supervision, operates on only four cylinders, with two missing, shall we call the two of the four operating "factors of safety" or "integral parts" of the engine? They are no less integral parts because inefficient management has neglected their associated mechanisms. Likewise, they provide factors of safety when other parts fall down. The committee hardly feels, however, with the provisions already stated in this report, that the question of nomenclature of chlorination, when used in conjunction with filtration, needs to be settled.

With underground waters, the problem of chlorination resolves itself also into one of investigation and administrative supervision of the source and its structural elements rather than into one of establishment of minimum quality of water before treatment. If a well water becomes turbid or is of excessive bacterial content, logic would demand corrective measures on the well or a change of source, not a standardization of chlorine treatment. Policy suggests chlorine application, properly controlled, together with close observation of untreated water, as in all other cases, whether the water be of surface, filtered, or underground origin. The committee wishes to emphasize that the use of chlorine should not be accompanied by relaxation of care with respect to all other activities concerning source or other treatment, any more than, in another field, typhoid inoculation of human beings provides an excuse for drinking sewage-polluted water. Economy and efficiency demand the maximum return on all elements of water treatment, before and including chlorine application. It is difficult to see why we should place any more limitations on chlorine than on other treatment processes, inasmuch as it is subject to no more idiosyncrasies than storage or filtration. In this discussion, however, it should not be forgotten that chlorine treatment is considered as a mechanism for bacterial elimination and nothing more.

CONTROL OF CHLORINE APPLICATION.

In the present state of our knowledge, it may be assumed that chlorination acts upon water with some degree of mathematical precision. If this hypothesis is correct it is advantageous to control the process of chlorination by balancing the various factors in the equation of the method. Wolman has stated the primary equation of chlorination as follows: Bacterial content and taste and odor vary directly and inversely, respectively, as the ratio of chlorine demand to chlorine supply.

In other words, as chlorine demand increases the chlorine supply must be increased also in order to keep bacteria and taste and odor at a minimum. If the chlorine demand rises without a corresponding increase in chlorine supply, bacterial content will increase in the treated water. If chlorine supply rises more than necessary to meet chlorine demand, then tastes and odors ensue. There are of course many elements entering into the problem which mask the relations indicated in the fundamental equation, but, for practical purposes, the generalization here outlined holds good.

The simplest form of chlorination control, therefore, should consist in maintaining a quantitative residual of chlorine at a definite station near the point of application of the chemical. What this quantitative residual should be is dependent upon the nature of the supply being treated; that is, upon its initial bacterial content and its general susceptibility to taste and odor. Trial and error will disclose soon the residual amount giving best results from all standpoints. As an initial attempt, the committee suggests the use of 0.2 p. p. m. free chlorine at a point of water travel about five minutes from the time of chlorine dosage. In some underground waters, the residual may be reduced safely to 0.1 p. p. m. after five minutes without losing bacterial efficiency and yet avoiding taste and odor, while in the case of a few surface waters, otherwise untreated, a residual of 0.5 p. p. m. at the end of five minutes may be required for bacterial elimination.

The residual chlorine may be determined by means of various indicators, such as orthotolidine, starch-potassium iodide, and crystal violet. The technique used in each instance may be found in any textbook on analytical chemistry. It is hardly within our province to repeat these methods in this report.

It is recommended by the committee that (1) the residual or excess chlorine tests be made at least twice a day on all waters and as many additional times each day on such waters as may show sufficient fluctuations in demand to require adjustments of dosage, and (2) the bacterial tests should be made at least daily, wherever funds and personnel permit.

ACKNOWLEDGMENT.

The committee wishes to express its appreciation of the aid given it by Mr. Abel Wolman, division engineer, Maryland State Department of Health, in the preparation of this report. Mr. Wolman has digested and summarized much of the data upon which the conclusions of this report are based, and has been closely associated with the committee throughout its preparation.

Mr. M. Z. **Bair.** As a member of this committee, I would suggest that the report presented be considered and recorded as a progress report. The committee is not unanimous on the acceptance of some of the statements as presented in the report, and there are some members who feel that certain phases of the problem have not been adequately covered. The question of limitations in the use of chlorine, or rather, the limiting factors in its adaptation to the treatment of a water, are matters which I feel should be given further consideration.

The promiscuous application of chlorine has in some instances given rise to unsatisfactory results due not so much to the inefficiency of this method of treatment, but due to its inadaptability. The conditions under which chlorine disinfection can or can not be used with assurance of reasonably satisfactory results in my opinion deserve further study. It would seem advisable, therefore, that the committee be continued for another year in order to give attention to certain phases of chlorine disinfection which have not been fully presented in this report.

Mr. L. A. **Geupel.** The State of Indiana has some 38 water supplies which use chlorination for sterilization. The water and sewage department of the Indiana State Board of Health cooperates and assists these supplies in every way possible. Those plants having efficient technical supervision render weekly reports to the water and sewage department covering the pumpage, amount of chemicals used, daily laboratory results, and difficulties which have occurred in operation. These reports are studied closely and information offered when needed. Those plants using chlorine which do not have efficient laboratory control send in reports as above, also submit weekly or daily mailing case samples as are necessary and the water and sewage department controls the chlorine feed as closely as possible. This is somewhat foreign to the real intent of the discussion, but while there may be limitations to chlorination as yet nothing has been presented to general practice which is more efficient and meets the various conditions—therefore chlorine must still be used. Specific information as rendered above not only assists in plant operation but acts as a double control upon the water-supply treatment.

Mr. W. H. **Dittoe**. The report of the committee appears to consider limitation of chlorination from the standpoint of possible bacterial efficiency which may be secured by the use of chlorine in treatment of water. In my opinion the committee should make a report dealing rather with the practical limitation of chlorine in water treatment, considering the field of usefulness of chlorination and its proper scope. There is certainly a practical limitation in the use of chlorine in water purification beyond which it is not expedient to go. There appears also to be evidence that there may exist a limitation of its bacterial efficiency, and it would seem that the committee should consider these various limitations.

Mr. C. A. **Emerson**, Jr. There is no doubt but that chlorination has a real field of usefulness, but its limitations are greater than was commonly believed four or five years ago. The public will not drink a water tasting of chlorine, and I do not feel that State organizations should expect them to do so. This generally means that in the case of small supplies, where the variation in rate of water consumption is great, there will be occasional overdosage or else the proportion of the chemical added is so small that there can be but little protection derived from it.

I believe the pendulum is swinging backward toward filtration, and hope that our committee can be retained for another year and make the subject of their investigation a consideration of where chlorination should be authorized for permanent use and just where the States should demand filtration, or at least something more than chlorination alone.

Mr. S. **Pincus**. The report of Mr. Morse, the chairman of the committee on control and limitation of chlorination, a special committee appointed in November, 1921, is not submitted as a committee report but rather as a personal discussion by the chairman, since two members of the committee, Mr. Bair and myself, receiving the report just prior to coming to this conference, did not feel that it at all adequately covered the assigned problem.

Mr. J. Frederick Jackson, director bureau of engineering, State Department of Health of Connecticut, then spoke on the plan of the American Society of Civil Engineers of having a sanitary engineering section in the society.

MEMORANDUM TO THE BOARD OF DIRECTION, AMERICAN SOCIETY OF CIVIL ENGINEERS.

The publication committee has recommended that a by-law be prepared to make provision for the orderly formation of professional divisions within the society, and the following is suggested:

ARTICLE VII. PROFESSIONAL DIVISIONS.

(1) A professional division of the American Society of Civil Engineers may, with the approval of the board of direction, be organized for the consideration of any engineering, scientific, or professional subject, provided that a number, satisfactory to the board of direction, of members of the society unite in making written request for such an organization. Such a division shall be designated as ——— division of the American Society of Civil Engineers, the blank being filled by the subject specialized.

(2) Members of the society of any grade may be members of the division upon enrollment without additional dues.

(3) For the convenient conduct of its professional affairs, the president shall appoint annually (from a list of names submitted by the section) an executive committee of five members to have charge of the affairs of the division under the guidance of the board. Other committees of the division shall be appointed by its executive committee.

(4) Expenditures for the purpose of the division chargeable to the society must be authorized by the board of direction before they are incurred and must be provided for in the budget approved by the board. No liability otherwise incurred shall be binding on the society.

(5) The board of direction of the society may, at 60 days' notice, suspend or disband any division.

This is to be regarded as a notice to the board of direction that the matter will come up for final action at the meeting of the board to be held at the time of the annual convention.

The conference adjourned at 5.15 p. m. until the evening session.

May 17, 1922, Evening Session.

The conference was called to order by Chairman Emerson at 7.30 p. m. in the Butler Building.

Mr. S. Fischer Miller, of the Pacific Flush Tank Co. of New York, spoke on Imhoff tank royalties. Mr. Miller stated that the first

Imhoff tank patent was taken out in the United States in 1909 and that all subsequent improvement patents are based on it. This patent expires in 1926. There is about $100,000 on unpaid Imhoff tank patent royalties due the Chemical Foundation, to whom these patents were turned over by the Alien Property Custodian. The overhead charges of the Chemical Foundation for collecting the royalties on the Imhoff tank patents may amount to 50 per cent of the fees, Mr. Miller estimated.

Mr. Keohan of the Chemical Foundation (Inc.), spoke on the connection of the Chemical Foundation with Imhoff tank royalties, and suggested that a committee of the conference be appointed to work with the Chemical Foundation in investigating the problems in sewage treatment.

Mr. C. A. **Emerson**, Jr. I feel this talk by Mr. Keohan and Mr. Miller has given us all information concerning the Imhoff tank royalties which will be useful. The executive committee of the conference is to have a meeting to-morrow and I will place the proposition before them to determine if they are willing to appoint a committee to work with the Chemical Foundation, as requested. I have talked with a number of our members and feel certain that if the executive committee should authorize the formation of a committee as requested that its members could only consider the public health benefits which would be derived by such experiments and should bear in mind that State health organizations could not become a party to a private commercial project.

Mr. C. A. Emerson, jr., chief engineer, division of engineering, State Department of Health of Pennsylvania, then delivered the report of the committee on milk supply.

Mr. H. F. **Ferguson**. In Illinois the division of foods and dairies is a part of the department of agriculture, and the department of public health has, until recently, done very little in a systematic manner to improve and assure the safety of milk supplies. The department of health is authorized by law to make analyses of samples of milk and to make such inspections as will protect public health, and the director of the department has this year undertaken vigorously the improvement of the sanitary quality of milk supplies in the State.

A "model" milk ordinance has been adopted by the department following conferences with the State department of agriculture, the University of Illinois, and representatives of milk producing and distributing organizations. Systematic efforts are being made to have satisfactory milk ordinances adopted in cities and emphasis is being placed upon the importance of pasteurization. In this work the division of sanitary engineering has aided by assisting in the preparation of the milk ordinance and by making a preliminary location study of pasteurization plants in the State by means of a questionnaire. By means of the questionnaire about 300 pasteurization plants were located and this information will be used as a basis for inspections of pasteurization plants by sanitary engineers of the department. All branches of the department will assist in promoting the adoption of suitable milk ordinances and in assuring clean milk supplies, but the inspection and control of pasteurization plants will probably be handled solely by the sanitary engineering division the same as are the water-purification plants.

A motion made by Mr. Dittoe was seconded and carried that this report be accepted by the conference.

Mr. Emerson then presented the report of the committee on milk supplies.

REPORT OF COMMITTEE ON MILK SUPPLIES.

Since our 1921 report nothing has occurred to change our general recommendations. There are, however, some features of our last report that may be emphasized and considered more in detail.

As sanitarians, we are principally interested in the prevention of communicable disease. There is ample proof that communicable diseases are being transmitted from the dairy herd to the milk consumer and from the milk handler to the milk consumer. We have evidence showing that bovine tuberculosis is prevalent among dairy herds, especially in the eastern part of our country, and year after year we have communicable diseases transmitted from the milk handler to the milk consumer.

The main objects of our attack are not reached until we definitely cut off these two channels of infection. The more bovine tuberculosis among children is studied the more its importance is realized. We must conclude that milk not protected from this disease at the point of production must be efficiently pasteurized, and information at hand indicates that milk infected by the herd is more resistant to pasteurization than milk infected by laboratory cultures.

Raw milk must be obtained from herds free from bovine tuberculosis, and the accredited herd plan, which is the only nation-wide plan ever attempted, should undoutedly be the basis for this work in all herds.

The report of the committee on tuberculosis of the United States Livestock Sanitary Association, dated November 29, 1921, under the subdivision entitled "Public health," stated as follows:

> One, if not the most effective, stimulus for a more general recognition of this question from a public health standpoint would be greater activity coming from our Federal, State, and local public health departments. There is evidence, however, of increased interest from these sources, and we may hope for more enthusiastic work and cooperation in the future.
>
> Our educational program, if properly executed, will no doubt be the means of greatly extending and making more efficient the sanitary supervision of our meat and milk supply, especially in those quarters where such work is incomplete or not at all in operation. As was suggested in discussing an educational policy, it is equally true that there should be greater cooperation on the part of the regulatory forces operating within the State for the protection of public health. As we analyze and go into the details of this great campaign on bovine tuberculosis eradication, aiming, as it does, to protect human life on one side and animal life on the other, its functions are more or less inseparable, for we can not give an effective service for one without the aid of the other.
>
> Educational campaigns on the relation of animal tuberculosis to public health should be conducted by health authorities. The health authorities should be provided with such information as will stimulate them to reach the public through educational departments, educational institutions, veterinary and medical colleges, veterinary and medical profession, other professions, hospitals, nurses, the press, bulletins,

organization, public speeches, and other conceivable channels. It is the duty of the above agencies rather than ours to do educational work pertaining to public health. It is our duty to produce reasons why this should be done and to disseminate knowledge and do educational work pertaining to the health of live stock as an economic feature and to find the ways and means of preventing loss to the live-stock industry. If we can show that the danger to public health can be corrected and other good reasons for using that feature as a means of correcting its cause, then the health organizations undoubtedly will properly inform the public, which in turn will stimulate the voluntary support of stock-men in a tuberculosis campaign.

This plan protects both the herd and the consumer. Also, there is an improvement in the general sanitation of the dairies operating under the accredited herd plan, for the plan requires a disinfection of infected premises, proper housing of animals, and protection of animals from outside infection.

The standard methods for the bacteriological examination of milk as adopted by the laboratory section of the American Public Health Association are not in universal use, and confusion is inevitable as the results of various methods are placed before the public health officials and milk consumers. More emphasis should be placed upon the importance of the use of standard methods.

This committee still supports the definition of pasteurization as given by the United States Department of Agriculture in Food Inspection Division 178. The only question concerning this definition may be the advisability of placing the maximum temperature in pasteurization at 145° F. There are now sufficient plants operating under this definition to prove to any open-minded individual that the definition is conservative and practical. Plants using this definition are competing successfully under commercial conditions with raw milk and with plants operating under any other definition of pasteurization.

Our former report indicated that a field was open to sanitary engineers to improve milk-treatment apparatus. We should consider at once the elimination of pockets which allow milk to remain in pasteurizing apparatus without treatment or only partial treatment. The recording thermometer is not being used as extensively as its importance demands.

The prevention of the transmission of communicable diseases from the milk handler to the milk consumer needs immediate attention. Milk delivered raw for domestic purposes should be handled by those who are examined for communicable disease within two weeks after employment and at least semiannually thereafter. This examination should cover those who handle this product from the time it is produced until it is delivered to the consumer. Also, there should be a similar medical examination of those who handle milk during the process of pasteurization and after pasteurization.

Mr. H. A. Whittaker. The supervision of milk supplies from a public health point of view is one which should be given serious consideration by sanitary engineers. A few State boards and departments of health have already placed at least a portion of their milk supervision work under their divisions handling sanitary engineering problems. This is the most logical division of the health department to handle the greater part of this work, especially the supervision of pasteurization plants, since such plants offer many engineering problems. More State sanitary engineers should give the matter consideration with the view of making this a part of their work before it is undertaken by some other department of the State government, where it may lose its significance from a health point of view. The Minnesota State Board of Health placed the work on the supervision of pasteurization of milk in Minnesota under the direction of the division of sanitation in 1917. There is probably no other branch of work which has been taken up by that division where more rapid progress has been made in improving conditions. Any of the sanitary engineers who are interested in the supervision work as carried out in Minnesota will be provided with information on this subject at any time.

The paper by Mr. Morse deals almost wholly with the theoretical efficiency of chlorine sterilization, omitting discussion on its limitations in waterworks practice. The comparison made in the report of chlorination with filtration and sedimentation processes fails to recognize the very much greater reliance on the human factor in chlorination. Also, because chlorination with other sterilization processes is theoretically capable of nearly 100 per cent bacterial removal, no matter how high the concentration in the applied water, and is at the same time much more easily reduced to zero efficiency, the consideration of standards and load factors for this type of water treatment must be handled differently than for sedimentation and filtration.

The dissenting members regret that a report giving their views was not submitted. In written discussions with the chairman, it was thought that these ideas had been clearly presented, and would be incorporated in the report. It is requested that the committee be continued and the subject referred back for further consideration.

A motion was made by Mr. Dittoe, seconded, and carried, that the committee be continued till the next meeting and that the secretary instruct the chairman of the committee that it is the desire of the conference to have the committee make a report on the limitations in the field of usefulness of chlorine in water treatment and the scope of chlorination.

Mr. Ellis S. Tisdale, director division of sanitary engineering, West Virginia State Department of Health, then delivered an interesting paper on "Good advice—A keynote to success in Wheeling's water supply campaign."

GOOD ADVICE—A KEYNOTE TO SUCCESS IN WHEELING'S WATER SUPPLY CAMPAIGN.

"State sanitation" was the title of an instructive paper read by Prof. George W. Whipple before the State Sanitary Engineers Association in Boston during June, 1921, on the occasion of their second annual conference. This paper dealt with the fundamental and governmental principles of State health departments, but it discussed in considerable detail the engineering aspects of State health work. Professor Whipple's admirable paper sets a high standard for engineering divisions to attain, but they will do well to try and reach this standard. His comments upon the methods which he considers most effective for lasting good to the community in question are noteworthy. In his opinion "good advice" which is the result of study and application and a thorough knowledge of conditions, is the keynote for success in making permanent gains in public health work by State health departments. Good advice are the two words which he uses to sum up the greatest usefulness of an engineering division. But mark this, it must be "good advice." This contains the idea that in some way or other the division has demonstrated its worth through helpful service and secured the trust of the people so that they are willing to come for help in time of trouble. Toward the end of his address he sums the whole matter up succinctly in the following statement:

> As a result of my experience as a practicing engineer, as a public health administrator, and a historian for the Massachusetts State Department of Health, I am convinced that the advisory functions of a State department of health carry with them more power for bettering sanitary conditions than the more drastic actions covered by permits, approvals, and orders, although without the latter the advisory powers would lack force.

This conviction as to the effectiveness of good advice has been gradually growing in the minds of the engineers of the West Virginia State Health Department, not only through the experience of a number of years in this State, but also by the observation of the success of the campaign for pure water supplies in the neighboring State of Ohio. Massachusetts also, the pioneer State in public health work, has consistently followed the advice policy with a good measure of success. An "intensified advice" policy for the largest city in the State, Wheeling, was adopted in West Virginia over a year ago to definitely reach the goal of a safe public water supply. It is my purpose to try and show how an adherence to this policy has at last achieved success in West Virginia, although the advice policy also had attached to it a lever, the lever of approval, without which doubtless the advisory powers might have failed signally. Before discussing this intensified advice policy it will be necessary to go back for about two decades and observe the struggle of the city of Wheeling to obtain a good water supply which began back in the nineteenth century.

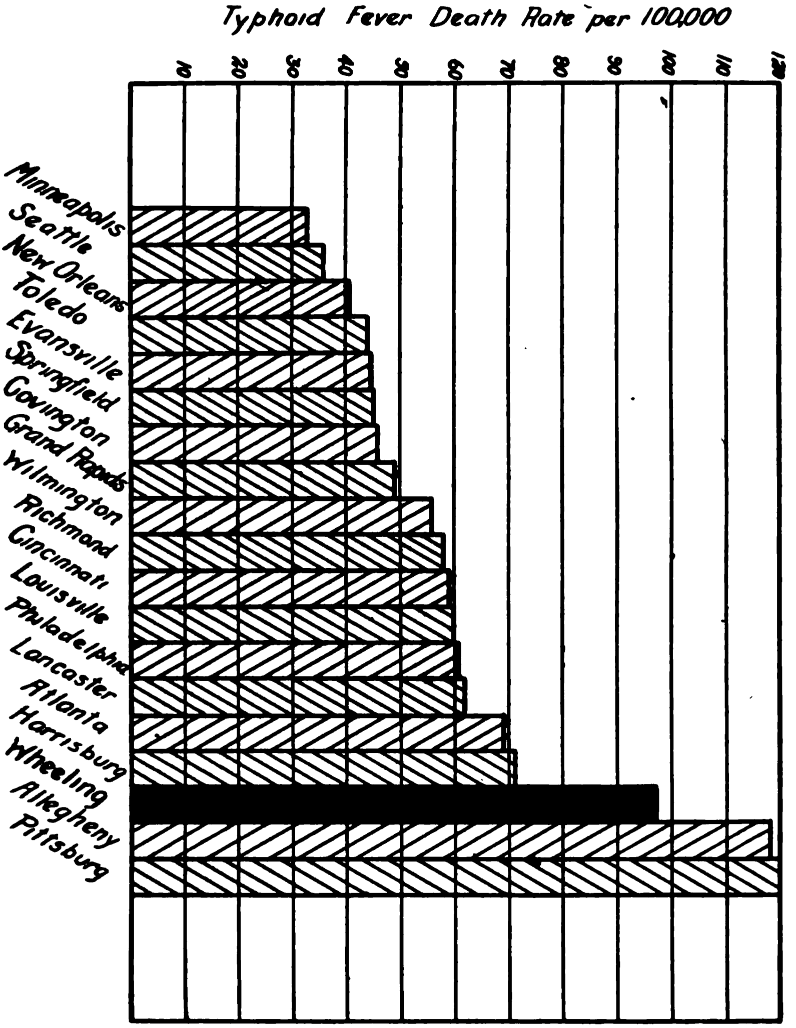
If we will look back 20 years and glance for a moment at Dr. George M. Kober's article and chart on "Conservation of life and health by improved water supplies" we can see the public water supply conditions for the years 1902–1906 which prevailed in many of the largest cities in the United States with the consequent high typhoid death rates. Wheeling, W. Va., with a typhoid death rate of almost 100, stood next to Pittsburgh, Pa., with a death rate of 120, which was at the very bottom of the list. At about this time the question of water supply improvement was agitated for Wheeling and though by 1910 nearly, if not every other city, had installed purification systems and reduced greatly the typhoid death rate. Wheeling's water supply for nearly 20 years was the playground of politics and caprice until 1922, when victory was gained.

In 1907 the city of Pittsburgh completed her filtration plant and Wheeling was afforded a good example to follow. Mayor C. C. Schmidt and the Wheeling council visited the new plant and declared their intention of immediately giving Wheeling pure water by adopting a filtration system. In 1907 Dr. S. L. Jepson, for many years health officer for Wheeling and West Virginia's first State health commissioner, recommended mechanical filtration strongly in a paper read before the Central States Water Board Association. His conclusions were reached only after a careful study of Wheeling's water supply problem.

When a decision was about to be made for a mechanical filtration system the element of the "Smith system of filtration" was injected into the question. This system, in which filter units were constructed in the bed of the Ohio River, had just been adopted in Parkersburg after a bitter fight between advocates of mechanical filtration and wells. It was a system which resembled rapid sand filtration in that filter beds were used which could be back-flushed though no chemicals were added, and it bore a likeness to wells in that a considerable proportion of ground water came into the underdrains of the filter beds from the surrounding plain.

The promoter of this "Smith system," who believed thoroughly in his plan of filtration, came to Wheeling in 1913 and urged the city council to adopt it. The erroneous idea that it was necessary to use harmful chemicals in the mechanical-chemical system of filtration, as it was styled, was spread broadcast while the benefits of the natural filtration were widely advertised. As a result of a huge campaign, the city council voted for the "Smith system of filtration." However, a reaction set in when the bond issue was presented to the people and it was voted down. Though the "Smith system" failed of installation, it accomplished one definite object. It prejudiced the minds of the people against rapid sand filtration and influenced them in favor of a ground-water or well-water supply.

Typhoid Fever Death Rate per 100,000



From Habers Chart Showing 19 Cities Using River Water 1902-1906

FIG. 1.

The logical outcome of the education of the people as to the wonderful yield of pure water which might be expected from the sand beds which surround Wheeling Island resulted in a campaign for a well system of water supply. The city engineer, together with one other local civil engineer, were authorized to prepare a report. This appeared in 1915 as a pamphlet entitled, "Report on the Proposed Well System of Filtration." These engineers as a result of their joint study recommended to the city that a system of wells such as they had investigated would yield a sufficient supply of pure water for Wheeling. However, no funds were ever made available to construct the system as outlined in the report. Political conditions were not right for going ahead with the project at this time.

In the meantime a study of West Virginia's public health laws and administration had been carried on by Taliaferro Clark, of the United States Public Health Service, and recommendations were made which became incorporated into the new public health laws adopted by the State Legislature in 1913. The creation of the division of sanitary engineering in this reorganization of the State board of health and the granting of the power of approval on new water supplies to the State health department had a vital bearing on the final action in 1922 to solve Wheeling's water supply problem.

In 1918 the "Smith system" and the well system having been attempted and nothing accomplished, the division of sanitary engineering met the city council, and by advice, written and oral and constantly repeated, at last prevailed upon the city to adopt chlorination as a method of treatment which would at least partially safeguard the city water until a pure public water supply could be provided. The advice by the State department of health that disinfection would be worth while has certainly proved to be valuable by the experience of the next four years, as shown in the accompanying chart.

The dense black areas on the chart show a typhoid case rate of 200 and 155 for 1917 and 1918, respectively. After the installation of disinfection apparatus there were but 28 cases of typhoid reported during 1919, and up until April, 1920, only 7 cases had been reported for the year 1920. This was a reduction of 85 per cent for 1919 compared with the average for the two previous years. The following year, 1920, showed still further reduction, until interruption of the chlorine treatment occurred. Now, what caused the jump as shown on the chart so that 37 cases in all were reported for 1920? Just this, the country-wide freight embargo during March and April, 1920, held up the chlorine tanks so that the city water went untreated for over three weeks. There was an immediate rise in the number of typhoid cases in the city reported to the health officer. A small epidemic occurred; 28 cases were reported up to July 1, and 4 deaths occurred in June alone. How sensitively this community responded to the change in the condition of the city water supply brought about by chlorination is certainly well illustrated by this four-year history.

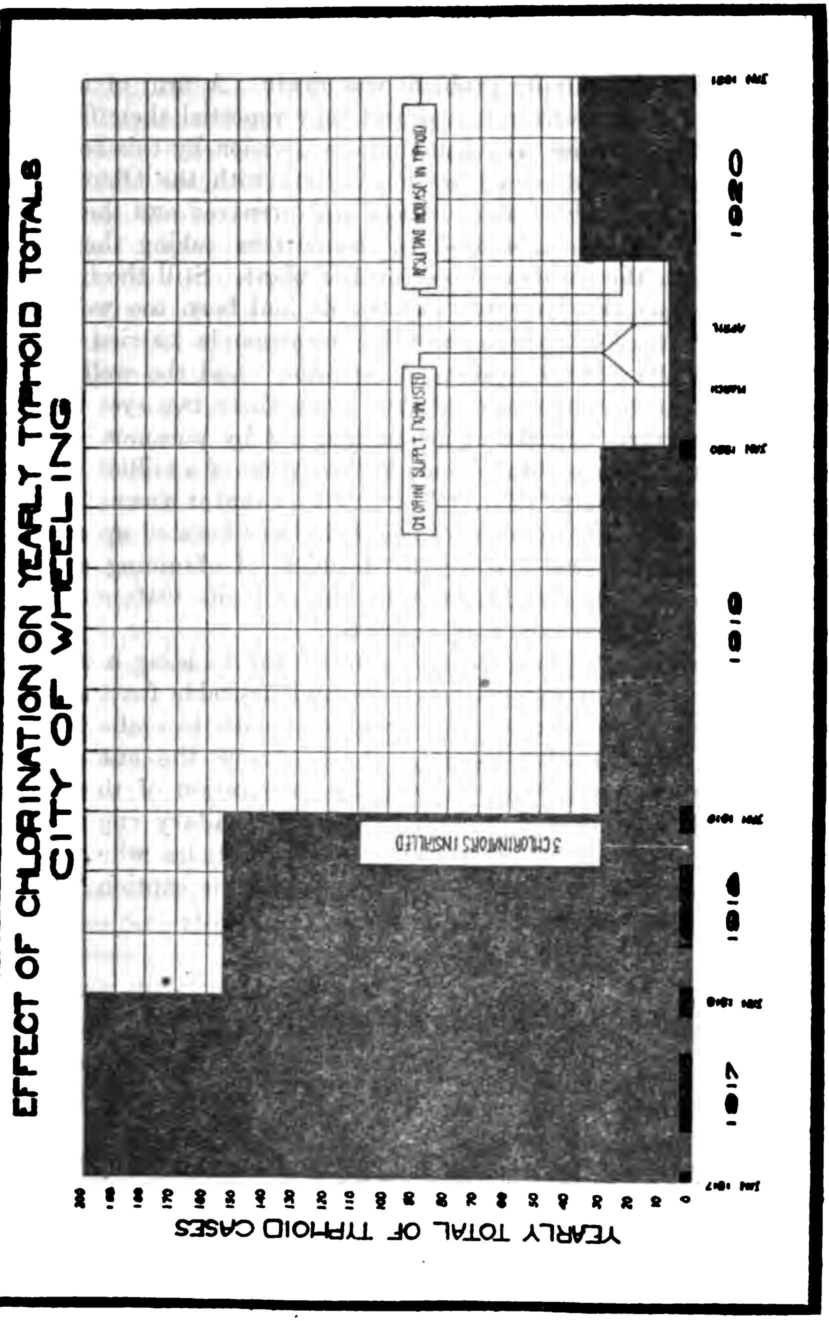

EFFECT OF CHLORINATION ON YEARLY TYPHOID TOTALS
CITY OF WHEELING
YEARLY TOTAL OF TYPHOID CASES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
JAN 1917
1917
JAN 1918
1918
JAN 1919
1919
JAN 1920
MARCH
APRIL
1920
JAN 1921
3 CHLORINATORS INSTALLED
CHLORINE SUPPLY EXHAUSTED
RESULTANT INCREASE IN TYPHOID

Fig. 2.

At the time of the installation of the chlorinating apparatus to disinfect the city water supply a new and effective city administration came into office. A pure water commission was formed and under the direction of the efficient city manager a comprehensive study of the water supply problem was made. A firm of reliable consulting engineers were retained and they reported their findings carefully. The outcome was a unanimous decision by this commission to install a rapid-sand filtration system with the Ohio River as the source of supply. A bond issue was prepared and the water supply question again submitted to the citizens, asking that they vote money for the construction of a filter plant. Still the hand of fate was against the project. The people had been too well sold on natural filtration by the intensive propaganda carried on to further both the "Smith system of filtration" and the well water supply. It had been emphasized that under these two systems the water was purified by natural means and not by poisonous chemicals. The attempt to obtain funds to the extent of a million dollars for a pure water supply failed. Who can deny that it was not a wise move for the State department of health to have insisted upon chlorination of the city water since this problem of obtaining a satisfactory public water supply for Wheeling still, in 1919, remained as much unsolved as at the start in 1900.

After this latest failure to provide funds for building a modern purification system it seemed necessary and desirable for the sanitary engineers of the State department of health to embark on a definite "intensified advice policy" to overcome the antagonism to rapid sand filters. After getting the cooperation of the newspapers of the community in May, 1921, the sanitary engineering division started a series of weekly editorial articles which were prominently displayed in the newspapers under the caption "Talks on Wheeling water."

PROGRESSIVE CITIES.

Throughout West Virginia there are numerous towns ranging from 2,500 to 18,000 in population who use for their public water supply a surface water not unlike the supply furnished Wheeling. The continued occurrence of typhoid fever over what is considered the normal rate, has brought home to them the short-sighted economy of obtaining cheap water but with a doctor's fees attached to the consumer's bill. Unfortunately the arrival of the doctor's bills are not heralded in advance and it finds the average family ill prepared to stand this additional strain. Consequently they have taken the water question to heart and have willingly bonded themselves to purchase this essential improvement. Most of the towns are small and maintain a good check on the expenditure of the money raised for the purpose of building a filtration plant. As the towns increase in size the opportunity for lessened money value to the city in its contracts becomes greater and is in some cities a question of fact.

Several of the towns in West Virginia which are either just building or contemplating building filtration plants are Shinnston, St. Albans, Elkins, Logan, and in the near future possibly Fairmont and Grafton. These cities have seen the utter futility of forcing a polluted water through the arteries of the city to be tapped by all the citizens with often very dire results as the history of the towns vividly testify.

Elkins, a town of 7,500 people, recently voted a bond issue of $125,000 for various improvements, including a filtration plant. The muddy Huttonsville branch of the Cheat River became impossible to chlorinate and at frequent intervals in the year, just at the period when chlorination was most needed after the hills had been washed down, the mud so carried prevented the chlorine gas from doing its work. Now a 2,000,000-gallon plant sufficient in size to last many years will be built and thus a clean and absolutely safe water will be supplied to the people.

St. Albans, a town of 2,500 people, situated on the Coal River, realized that no real expansion could be made in the growing town unless the newcomers were assured a satisfactory water supply. Not only were the people recipients of silt and organic matter, but leaves and sticks were pumped through the mains. Surely it was worth while to stint one's self a little to improve this condition. A rather unique method was used to obtain the money. The general manager, a well known business man of that town, pledged his word of honor that these bonds sold publicly would have their interest secured by him personally. That is, a promise was sufficient and the bonds sold quickly. Not all cities could boast of that method of raising money, but it shows the many ways in which a town or its individuals may, if they are determined, raise the necessary funds to provide these improvements.

Slowly the cities are falling in line and providing their citizenry with a commodity that is clear and wholesome, with water that is safe, and that may be consumed in any amount without fear of sickness or maybe death. How long will the larger cities supinely continue to use a foul and unsafe water?

Just before this intensive educational campaign started a newly elected city council appointed another pure water commission to attempt to solve the local water problem. Despite the thorough manner in which the question had been studied by the previous commission, which was composed of men competent to judge the matter, this new water commission listened with great eagerness to a brand new proposal for another well supply, which it was promised could be installed for a relatively small amount of money and was supposed to have particular merit since the water was to be pumped by compressed air. A favorable vote was passed by the city council to accept the proposal of the company advocating this system provided the State department of health would approve it. In all probability this system would have been installed but for the law requiring the approval of new projects by the State health department. Approval was refused, since it was felt after careful examination that both quantity and quality of water derived from ground-water sources were uncertain. Great indignation was manifest at the council meeting and the idea was given expression by prominent and powerful politicians that it would be well to wait before making any decision about the water supply and go before the State legislature in 1921 to repeal the present public health law, which gave supervision of the plans for new water systems to the State health department.

This was the state of affairs when the weekly water supply letters made their appearance throughout the spring, summer, and winter of 1921 and the spring of 1922. In January, 1922, a new city government was installed in office and officials came into power who had a strong desire to better civic conditions and were in sympathy with installing a modern water purification system. During all this time the steady stream of articles illustrating the means for purifying surface waters, and counteracting the idea that the well system was the only one to produce a water fit to drink were being read each week. Thus, a sure foundation was laid for the intensive program later on to carry the bond issue for building a proper filter plant. Under the leadership of a new city manager the plan of 1919 for mechanical filtration was revised to fit the changed conditions in the rapidly growing city. This plan was adopted unanimously by the city council and a short intensive campaign for a $2,000,000 bond issue to build the plant inaugurated. The intensive campaign was vigorously prosecuted and all the modern methods of putting across bond issues adopted.

1. First and most important the campaign was personally directed by the city manager, who had the confidence of the business men of the community.
2. A carefully laid-out program of mass meetings in all the different wards of the city brought detailed information to every citizen.
3. Civic organizations, such as the Rotary, Kiwanis, and Lions Clubs actively pledged their support and asked each member to see 10 other men to explain away any objections. Also, 15 speakers from these clubs gave four-minute speeches each night in all motion-picture houses during the last week of the campaign.
4. Fifteen thousand pure water buttons were distributed among the school children of the city, and school teachers emphasized what pure water would mean for Wheeling.
5. Fifteen thousand little vest-pocket size pamphlets were prepared, setting forth every detail, such as cost of plant, taxation question,

unemployment relief situation, public health betterment, fire insurance rate reduction, soap hardness reduction, and lessened plumbing costs.

6. The chamber of commerce and interested citizens contributed a sufficient fund of money for full-page advertising for a 10-day period preceding the election day, and a trained "ad" writer arranged the display.

7. The women, organized by the president of the League of Women Voters, proved a strong ally for the cause and they were supplied with machines to assist in getting the vote out.

8. On election day every precaution was taken to get a big vote out by having industrial works close early. Large employers of labor personally urged their men to vote. In fact, no stone was left unturned to put the issue through since conditions might never again be so favorable. A 3 to 1 majority was the verdict.

It may be argued that the engineering division spent too much time and effort on one particular city in the State in prosecuting this campaign. However, from my point of view I deem the success of this campaign worth all the money which the State of West Virginia has appropriated for the carrying on of all the six divisions of the entire State department of health since it started its public health work in 1913.

The State Health Department appropriations since its start in 1913 have been as follows:

1913	$10,636	1919	$45,000
1914	10,636	1920	45,000
1915	15,457	1921	60,000
1916	15,457	1922	60,000
1917	25,000		
1918	25,000	Total	312,186

LOSS TO WHEELING CITIZENS IN DECADE 1910–1920, NINE YEARS, FROM TYPHOID FEVER DUE TO A HIGH TYPHOID DEATH RATE OCCASIONED BY DANGEROUS PUBLIC WATER-SUPPLY CONDITIONS.

WATER-SUPPLY CONDITIONS.

Raw Ohio River water furnished for public water supply.

Pollution of Ohio at Wheeling great, due to discharge of sewage of Pittsburgh and other large cities above Wheeling into the Ohio River.

Financial losses to Wheeling citizens.

Expenditure by private individuals for medical services and drugs, 3,300 cases, at $50	$165,000
Private expense of nursing services, 800 cases, at $100	80,000
Loss of time by wage earners, one third of cases, 6 weeks, at $5 per day	198,000
Value of lives lost, 220, at $4,000	880,000
Funeral expenses, 220, at $150	33,000
Total estimated loss for year period	1,356,000

IMPROVEMENTS BROUGHT ABOUT.

Chlorination established in December, 1918, following vigorous campaign by State health department.

Action by pure water commission and city council in 1920 authorizing preparation of mechanical filtration plant plans following refusal of State health department to permit use of wells in Ohio River.

Compare the totals in each of the above lists. The expenditure of money in Wheeling as a sacrifice to preventable typhoid fever has totaled over one and one-third million dollars in a decade. To maintain the entire State health department from 1913 to the present time has cost less than $320,000, and I feel that if the State department of health since its inception had accomplished nothing else but the bringing of a pure water supply to Wheeling in the nine years of its work the expenditure of money would have been justified many times over.

West Virginia has been a backward State in public health work, in sanitation, and in its general development because of its comparative isolation, but there are many other States in the Union to-day behind West Virginia. It has therefore seemed worth while to sketch the experience of Wheeling, her water-supply struggle, and the part that the sanitary engineers of the health department are playing in trying to reduce the typhoid toll from water-borne diseases.

Advice, backed up by the power of approval on public water supplies, has played the leading rôle in winning the victory for a pure water supply, first, in bringing to pass disinfection of the city water and later through an intensified program dispelling the erroneous idea of the people regarding mechanical filtration and helping the passage of a bond issue of $2,000,000 for a modern water-purification system.

The conference adjourned at 10 p. m. until the following morning.

May 18, 1922, Morning Session.

The conference was convened on May 18 at 9.30 a. m. in room 2144, Interior Building, by Chairman Emerson.

Mr. Clarence Marsh delivered a paper on "Electrolytic Production of Chlorine with Special Reference to Water Treatment." There was a general discussion of the paper.

ELECTROLYTIC PRODUCTION OF CHLORINE, WITH SPECIAL REFERENCE TO WATER TREATMENT.

Chlorine has become such an important factor in the preservation f health of our citizens that any new facts on the situation will be welcomed by the general public.

Chlorine can be made on the job in simple electrical apparatus. Chlorine is made by passing a direct current of electricity through a aturated salt solution. Salt is the cheapest commodity known. Electric power is available anywhere. It may be purchased at easonable rates for power purposes or it can be generated as direct urrent by means of oil, gas, or steam power in small or large units. Under reasonable conditions the cost to the consumer will be much ess than if chlorine compressed in cylinders or drums is purchased.

Not only is the cost of power and salt less than the compressed or iquid chlorine but the outstanding feature is the extremely low ost of materials for repairs and renewals, about 1 cent per pound or small installations and less than one-half cent for large installaions. In small amounts you can make chlorine for one-fourth of he cost of liquid chlorine, including renewals of control apparatus, nd in large amounts for one-half the cost. Reasonable prices for lectricity, for power purposes, and salt are assumed.

Chlorine and caustic soda will be used more and more as it is enerally known that it can be made available any where, at any ime, and in any amount by simply passing a direct current of lectricity through a salt solution. In addition it eliminates any ecessity for storage of chlorine under high pressure.

Consider a small water plant where the amount of chlorine to be sed might be as low as 3 pounds daily. The amount may vary rom 1½ to 4½ pounds. What kind of an apparatus is required to make this amount of chlorine on the job?

It consists of a hard rubber or wood battery box containing one ell, total weight 67 pounds, occupying 1¼ square feet floor space, nd height about 18 inches. To supply this battery with a salt olution we can use a small wood tank about 3 feet in diameter and bout 4 feet high, giving from one week to two weeks' supply. By proper arrangement of construction of the tank the salt may be umped into it and a pure salt solution withdrawn ready to feed to he battery.

Direct electric current necessary for the operation of the battery is supplied through a small motor generator set of about one-fourth kilowatt capacity. The amount of current delivered to the battery is controlled through a rheostat located on the electric control panel. The amount of chlorine made is then indicated by the chlorine ampere meter on the control panel. This can be fixed at any point within the range of the apparatus. The amount of chlorine generated and dosed to the water can be varied automatically with the flow through an electric and mechanical device connecting the flow meter with the control panel for the battery. The rate of dosage may vary from one-fourth pound to 4½ pound daily rate.

In another case where electric power is not available we can generate it. For instance, the modern self-contained power light unit can be used. A direct-current generator of three-fourths kilowatt capacity directly connected to a single-cylinder kerosene engine is available in the market to supply direct current at 25 amperes and 30 volts. For electric lighting a storage battery is used in connection with this unit, giving it a wider range of power, namely, up to about 1¼ kilowatts capacity. This power unit would be sufficiently large for a water plant requiring up to 24 pounds of chlorine daily.

For the production of this amount of chlorine we would use a multiple type of battery with this apparatus. A battery of 10 small cells, each cell weighing about 35 pounds each, having a capacity of 10 amperes to 40 amperes and a maximum capacity of 24 pounds of chlorine, might be used. This battery would take a floor space of 4¼ feet by 3 feet or 8½ feet by 1½ feet, total of 13 square feet. It can be put on a shelf or on the floor the same as any storage battery. The units are connected up to a hard rubber pipe which delivers the chlorine directly to the water to be treated. The amount of chlorine can be varied within wide limits, 2½ pounds to 25 pounds daily rate. These are typical installations for small plants. These batteries will operate over a year at a time without any other attention than to see that the electric current is properly applied at the desired rates and that the cells are kept filled with salt solution, which is handled automatically through simple devices which are not subject to corrosion or clogging. When a cell or a group of cells need renewal they can be replaced by other cells held in reserve and the original cells shipped back to the factory or the renewals or repairs can be easily made by any mechanic. The electrolytic cells forming the battery can be small and light and can be handled and removed from the battery boxes by one man. No machine work is necessary on any of the parts, as they are all standard and fit together easily. None of the repair parts are expensive. The materials used are hard rubber or hard fiber, graphite, asbestos paper, and steel. It is a simple matter to lift the cells out of the box and take off the side plates with the asbestos paper diaphragms. New diaphragms or new anodes are put in place and the cell is ready for another year's run. What could be more simple?

Annual cost of maintenance for materials per pound of chlorine per 24 hours.

1¼ to 2 pounds graphite, at $1 [1] per pound	$1.25–$2.00
Hard rubber or hard fiber covers will last indefinitely, say 10 years; 1 pound	[1] .50
Asbestos paper, 1 pound	[1] .50
Steel and miscellaneous materials, 1 pound	[1] .50
Total annual cost for materials per pound chlorine per 24 hours	2.75– 3.50

The batteries can be operated continuously or intermittently. A group of cells in the battery can be cut out or the chlorine from them diverted when the requirements are low. They can be cut in again when the requirement for chlorine is greater. Any number of cells can be connected up for direct dosage to the water or for any other purposes. Some of the cells not in service may be used to generate chlorine for making hypochlorite.

Chlorine is generated under a slight suction and is drawn off and applied directly to the water without preliminary mixture of water through ordinary methods of withdrawing gas from any apparatus, viz, by air, steam, or water ejectors, pumps, or by any other suitable mechanical devices. There are no valves to corrode or to be stopped up. There is no necessity for extremely accurate control of the suction used in withdrawing the gas because the amount of chlorine is regulated by the amount generated in the battery. No amount of suction will draw out any more. The chlorine is produced in proportion to the electric current passing through the battery. The electric current can be hand regulated or can be automatically controlled.

The mixture of caustic soda and chlorine generated in the battery can be used as a disinfectant as well as a sterilizing agent. Every municipality has occasion to use cheap disinfectants for health protection.

The general application for institutions as well as for water and sewage effluent is quite apparent. The apparatus can be loaded on a truck, trailer, car, or boat and can be moved anywhere. The batteries will operate in the coldest weather. These batteries will operate wherever any other devices will operate. They need no more attention than a periodical inspection, as in the case of any other apparatus. The batteries can be started up automatically by turning a switch to turn on the electric current or to start the power unit. The rate of chlorine can be varied by hand or automatically by changing the amount of current delivered to the battery. The devices for withdrawing the chlorine can operate continuously or can be cut out or stopped in the most practical manner. The salt-solution feed should be turned off during long interruption of current to save salt. The battery must be filled up again before turning on the electric current.

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[1] Prices for larger demands.

But little attendance is required to make up the salt solution. It consists of filling up a portion of the wood tank with salt, turning on the water, and, in the case of impure salt usually secured on the open market, by adding a small amount of soda ash and caustic soda to the salt solution to purify it. The only attendance outside of this is to start and stop the motor-generator set and regulate the electric current. Electric apparatus usually saves labor and material. The spare time of the attendant is ample to take care of the renewals on the job.

Aside from the attendance, the operating and the maintenance cost per pound of chlorine per 24 hours is as follows for different power rates compared with liquid chlorine:

Making chlorine gas.

Kilowatt-hour rate.	½ cent.	1 cent.	2 cents.	3 cents.	4 cents.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*
Renewals of cells including depreciation $\frac{\$2.75}{360}$[1] to $\frac{\$3.50}{360}$ (days) (days)	¾	¾	1	1	1
Power, 1½ kilowatt-hours direct current or 1⅞ kilowatt-hours alternating current (80 per cent transformable efficiency) for larger apparatus	¾	1½	3	4½	6
Salt, 4 pounds at ½ cent	2	2	2	2	2
Total	3½	4¼	6	7½	9
Credit caustic soda, 1¼ pounds, at 3⅕ cents	4	4	4	4	4
Maintenance cost	½	¼	2	3½	5

[1] The smaller rate is for the larger cells, which are usually installed where power rate is a minimum; the larger rate is for the smaller cells, usually installed where power rate is higher.

Making liquid chlorine.

	For small installations.	For large installations.
	Cents.	*Cents.*
Depreciation and renewals	16	1
Chlorine	6¼	5¼
Freight and cartage	2	1
Total	24¼	7¼

These costs are considerably less than for other methods when you consider that renewals are included.

For small consumers of chlorine the big item of cost when using liquid chlorine is the cost of upkeep of the control apparatus. A liquid chlorine control apparatus installed costing $600 to $800 for using 1,000 pounds of chlorine yearly may last three years, or not as long if used intermittently. This gives a cost for replacement of the control apparatus excluding yearly repairs of 23 cents per pound.

The net savings per pound of chlorine by making chlorine on the job in batteries may be more than 25 cents for every pound of chlorine consumed by the smaller waterworks and as much as the total cost of chlorine to the largest waterworks.

Chlorine gas, now a recognized means of sterilizing water, can be produced by a battery at a cost materially below that of the liquid gas including all maintenance on either generating or control equipment as well as operating costs. The gas is generated only as it is needed and no storage of gas under high pressure is required. The gas is removed by suction as fast as it is generated. There is no sensitive control apparatus exposed to corrosive action of chlorine gas, thereby requiring frequent attention. Repairs, if needed, can be made by any mechanic or electrician. The devices are equally well suited for very small or large demands for continuous, intermittent, or emergency use without deterioration.

A battery can be used which is simple, compact, convenient, portable, and of universal applicability.

PROGRAM FOR THE NEXT MEETING.

The conference then discussed in open forum the program for the next meeting. The following points were decided:

1. The corresponding secretary should ascertain within the next 60 days from each committee chairman whether his committee will have a complete report available at the next meeting. Then the corresponding secretary should communicate with all members of the conference to find out which reports they are most interested in and which ones the individual engineers would be prepared to discuss.

2. The corresponding secretary should write each member to ascertain what special topics he would like to have discussed, and which he would be ready to open the discussion in. From the replies the executive committee will determine at least 60 days before the next meeting the topics and reports which are of widest interest and arrange the program with names of engineers leading the discussions.

3. An effort should be made to have a stenographer at the meetings to take down the conference transactions.

4. The executive committee should endeavor to arrange for one joint session with the State and Territorial health authorities conference at which all sanitary engineering subjects are taken up.

5. The program for the next meeting should consist of not more than three committee reports, and the rest of the time should be alloted for discussion of special topics. Definite time limits should be set for each report and topic and adhered to strictly by the chairman and the members. Copies of the program and of each committee report to be discussed at the next meeting should be mailed each member at least 30 days before the next meeting.

WATERWORKS OPERATORS' CONVENTIONS.

In an open forum the conference then discussed what the various States are doing to instruct waterworks operators in proper plant operation.

Mr. E. L. FILBY. The primary question I bring up is what methods are being used to bring home the essential points of operation detail necessary to secure safe water; or, in other words how to educate the small plant operator. We can not hope to get our small plant men out to courses such as are given in Texas and we have had little success in getting these men out to conventions of the water association in this section. I am getting out every month a five-page mimeographed letter called "Sewat" in the interest of water treatment and sewage disposal. This is sent free to every waterworks man in the State and to others interested. The men do not seem able to leave their own locality, as they are usually charged with the maintenance of both water and light utilities. It is the small plant men that I am especially interested in.

Mr. H. F. FERGUSON. Since the division of sanitary engineering was established in Illinois there has been under consideration the holding of conferences for filter-plant operators. Such conferences would be held at least once a year at different places where filter plants are in service so that any instruction or discussion might be illustrated by inspections to the filter plants.

The division was only established in the early part of 1916 and the war interfered with carrying out the contemplated plans. Following the war and the return of several members of the staff from military service the division has experienced the loss of the chief engineer and some other members of the staff, and thus the holding of the contemplated conferences was again delayed. I have been very interested in reviewing the printed records of the conference held in Ohio and am hoping that Illinois can carry out a similar conference which has been now under consideration for several years.

Mr. S. PINCUS. The first convention of Connecticut waterworks officials was held in Hartford, Conn., on April 18 under the auspices of the State sanitary engineering division. About 100 persons were in attendance, mostly waterworks superintendents. As there are very few filtration plants in that State, the discussions were principally concerning stored waters. Special interest was shown in methods for the protection of watersheds, analytical control, and algae treatment. The success of the conference was indicated by the vote to make it an annual event and to have the proceedings printed at the expense of the waterworks officials.

I wish to point out that such State conferences of waterworks officials should not be narrowed down to filter-plant operators or discussions solely on the treatment of water, but should rather include technical directors or supervising officials from each of the local waterworks and take up all sanitary problems, large and small, relating to waterworks practice.

Mr. H. E. **MILLER.** A waterworks superintendents' convention was organized in North Carolina last year as a State section of the American Waterworks Association. A very successful meeting was held last year, and the enthusiasm is growing fast for the convention, which will be held this year beginning November 14. We have given every possible assistance to this convention, feeling that operation could be greatly improved by the contact that superintendents and plant operators would make with one another. We have found it successful beyond our fondest expectations. Our superintendents are now writing circular letters to all the other superintendents creating a greater interest. We multigraph and prepare all correspondence. We thus check and censor. The main problems of operation are covered in selected papers presented by selected men. We help prepare the papers dealing with treatment and allied subjects. We thus get before the men the desired information, but it comes from a superintendent or operator and can not be classed as propaganda.

Mr. L. A. **GEUPEL.** Each year there is held a three-day meeting of the Indiana Sanitary and Water Supply Association whereby all phases of waterworks' operation are taken up in papers and open-forum discussion. At the last meeting in March there were 150 members present and an excellent program was given. Considerable time is given in general open meeting on plant operation, which is interesting to the water-plant superintendents.

Mr. Dittoe spoke of the recent Ohio Water Works Conference and the interest created among the State waterworks' operators since the meeting.

Mr. C. A. **EMERSON**, Jr. Mr. Miller and Mr. Dittoe have perfected two different types of associations and each seems to have its merits. There is one point in common, and that is a desire to have the waterworks men feel that their personal interests and benefits constitute the only reason for existence of the organization. We have in

Pennsylvania an independent waterworks association. It is a going organization financed by waterworks men. They have their annual meetings and these are well attended. The subjects under discussion are varied, including the financial as well as scientific features of waterworks operation, and I believe that if such an organization could be perfected in all of the States it would be of benefit.

Doctor Frost spoke on the program of the stream pollution studies of the United States Public Health Service which include: (1) Study of biochemistry and bacteriology of sewage; (2) study of pollution in tidal waters; (3) study of Ohio River pollution. He stated that there are three ways of judging the pollution of a stream: (*a*) By a sanitary survey; (*b*) by bacteriological and chemical analyses; (*c*) by epidemiological evidence. From the volume of flow of a river and the population contributing sewage, an estimate of the extent of pollution at a point can be obtained. The Ohio River investigation was made to determine the extent of pollution at various points. It was found that the total amount of industrial wastes in the Ohio River was considerably in excess of the amount of sewage from the population. Studies were made at Cincinnati on the number of bacteria per capita per day in human feces. It has been found result of these studies that it is possible to estimate reasonably se the degree of bacterial pollution at various points in the Ohio River at a certain date. The report on the Ohio River investigation will be printed this fall. Messrs. Pearse, Jordan, and Forbes form an advisory board to the Public Health Service for stream-pollution studies in the future. Further study will be made on the relation between raw water and effluents from waterworks plants.

IMHOFF TANK PATENTS.

Mr. Emerson, in a discussion of Imhoff tank patent royalties, stated it was the consensus of opinion of members of the conference that it was not the policy of State health departments to collect Imhoff tank patent royalties or to assist in their collection. Upon request from the Chemical Foundation for a list of sewage treatment works in each State, the State health departments would send such lists as available as a matter of public information. If the Chemical Foundation desires to donate a certain sum for research in sewage treatment and disposal, such a donation will be considered the same as any other donation for scientific research and should have no qualifications.

Mr. C. N. Harrub. I do not feel that it can in any way be considered within the province of the division of sanitary engineering of a State board of health to assist the Chemical Foundation in collecting royalties on Imhoff tank patents, but upon request the State board of health should furnish a list of sewage-treatment plants in the State. I have already sent the Chemical Foundation a list of such plants as we have on record. I concur in the opinion expressed by our chairman.

Mr. Dittoe also expressed his agreement and made a motion, which was seconded and carried, that the corresponding secretary write the Chemical Foundation that it is the opinion of the Conference of State Sanitary Engineers that when the Chemical Foundation is ready to consider research work in sewage treatment and disposal, and sets aside a certain sum without qualifications for such investigation, the conference will be pleased to appoint a committee to confer with the foundation as to the extent of the research work and the problems to be investigated.

Mr. Bair made a motion, which was seconded and carried, that the State sanitary engineers should render no assistance or give information in the collection of Imhoff tank patent royalties, except such information as they have on record in public files.

SHIPMENT OF WATER SAMPLES.

Mr. Harrub then discussed the matter of shipment of water samples according to Tennessee experience. He described a new container being used by him, a two-walled case with suspended can, based on the vacuum freezer plan, each container weighing about 15 pounds, including ice and water sample. He believed each container would cost about $10 if purchased singly, but that he hoped the price could be reduced to about $7.50 when purchased in 50 or 100 case lots. He stated that in Tennessee it is found necessary to ice samples sent in from a large part of the State. Many sections require more than 24 hours to get samples to the laboratory, and, unless iced, the analyses are sometimes misleading. On account of the fact that the standard practice has been to ice samples, he believes it is also desirable to ice the samples, at least until it has been definitely shown by comparative analyses that under 24 hours there is no appreciable change in the water. He believes that field plating will ultimately be the method employed by State boards of health, but until that time arrives some States will be obliged to ice samples sent to the aboratory.

Mr. Dittoe raised the question of advisability of icing samples which are less than 24 hours in transit.

Mr. L. A. Geupel. The State of Indiana uses a box container approximately 5 by 15 by 15 inches, in the center of which is a built-up galvanized iron ring. This ring holds the galvanized can in position. Inside the galvanized can the sterilized bottle is placed.

The water and sewage department uses two types. The above-named is termed the "chemical," which furnishes the laboratory with sufficient water to make a sanitary chemical and bacteriological analysis. Where the source of supply is known, namely, public, the "bacteriological" container is sent, which is 5 by 15 by 15 inches, with compartments for the small bacteriological cans holding small bottles. All containers must be iced properly. Accompanying each container is a mailing envelope containing full instructions how to take samples and blank spaces for information desired. There are no charges made for analyses, the applicant agreeing to pay the express charges to and from the laboratory. The water and sewage department laboratories operated by the department make about 3,000 analyses annually and have had no trouble from containers.

Mr. H. V. **Pedersen**. The Iowa State Board of Health laboratories are located at the State University at Iowa City and all samples of water collected must be sent there for analysis. When anyone in the State wishes to have a certain source of water supply tested, they are requested to write to the chief of the water laboratories, who sends them a container together with instructions as to how to collect the sample. A fee of $1 is required by the legislature for every sample analysed.

The container consists of a pint glass, glass-stoppered bottle that fits snugly into a galvanized-iron jacket. Two bottles with their jackets are then generally placed in a wooden box 1 foot square where ample room for ice and straw is provided. It is very seldom that any bottles are broken during transit.

If any question arises as to the correctness or fairness of the analysis, due to the length of time the sample was in transit, or method of collection, a second sample is required with request that more care be taken. When water samples prove unsatisfactory, a survey is generally made by the engineer of the State board of health, who then gives an interpretation to the analysis. Due to the lack of personnel it is not possible for the engineer of the board to inspect all water supplies that are reported as "suspicious" and an attempt is made only to go to the places from which a written request has been received.

In order to facilitate matters of water collection and analysis in questionable cases the State board of health has authorized a number of private laboratories in the State to analyze water. These laboratories must meet certain requirements and all their work along this line must be reported to the chief of the State laboratory. This not only keeps many private concerns from doing work that the

State has no check on but also brings laboratories nearer to the field if any legal question should arise as to the fairness of the test.

There is the very best possible cooperation between the engineer of the State board of health and the chief of the water laboratories, and in view of the fact that there are so many limitations to our department, we feel that we have worked out a very satisfactory method.

Mr. H. A. WHITTAKER. The policy of a State board or department of health receiving samples from various sources throughout the State on which they make analyses and report back to the owner of the supply is, in my opinion, a very dangerous one. Investigations by the Minnesota State Board of Health covering 730 unsatisfactory sources have shown that if water supplies are to be judged only from an analytical point of view, 46 per cent of the unsafe supplies would have been overlooked. On the other hand, it frequently happens that unsatisfactory analytical results are obtained on existing water supplies which are satisfactory in so far as their location, construction, and operation are concerned, and the analytical results should not permanently condemn the supply. I believe that no opinion should be given by a State board or department of health on any existing water supply without a complete field survey, together with the necessary analytical examinations, and that the investigation work should be done by a competent person. If complete information is obtained, it is possible to place the proper valuation and interpretation on the data collected through the field survey and the laboratory examinations, and this data constitutes a basis on which recommendations can be offered to correct any existing defects which may be found. This opinion is, I believe, generally accepted by all sanitary engineers, but it seems that certain States feel that it is necessary to continue the examination of samples of water because they fear the results of a change of policy. It is my opinion that the sooner the facts are brought to the people and the policy changed the better the public will be served. These few statements by no means cover the arguments against the practice referred to in this discussion, but are merely presented for consideration.

Mr. C. A. EMERSON, Jr. In most court cases of which I have knowledge the question has been raised as to whether the samples when analyzed at the laboratory were representative of the water as collected. Furthermore, irrespective of court cases, is it not necessary that when an engineer reads the laboratory report he should be reasonably sure that he has a correct basis on which to judge the purity of the supply? Does not this mean that in the future we are going to turn more and more to field plating of water samples or to the use of a traveling laboratory which can be sent into the field to make bacteriological examinations?

Mr. Harrub's container appears to have merit and I hope will prove to be all that he feels it is. Its use is rather expensive, but it would not be so expensive as field plating or a laboratory truck. With Mr. Harrub's permission, we will secure some of these containers and give them a thorough trial in our State.

COLLECTION OF WATER SAMPLES.

Mr. H. A. **Whittaker.** The Minnesota State Board of Health has for a period of approximately 20 years required that all samples for examination be collected by its own representatives. The samples are collected in the field and the bacteriological examination is started in the field. A description of the field equipment which is used in the collection of these samples can be found in Public Health Reports, volume 29, No. 20, May 15, 1914. Certain changes have been made to improve the field outfits described in that report, and detailed information concerning these changes will be gladly given on request.

Mr. Emerson stated that water samples can be collected satisfactorily by local health officers who have been carefully instructed as to the proper methods of sampling and the information to be forwarded on cards with the samples. Mr. Emerson also stated that it is not the proper function of State health department laboratories to make analyses of water of any private well when any request is received. This view was concurred in by the conference.

Mr. H. F. **Ferguson.** Illinois, besides being an important industrial and commercial State, is an important agricultural State, and thus there are many private wells on farms and in rural communities. The State department of health, therefore, considers that it would be unfair to the owners of these private wells to adopt the policy prevailing in Minnesota and not make analyses of the samples of water from private wells. We should prefer, of course, not to make analyses of samples from any wells that can not be inspected by one of our sanitary engineers or analysts, but since it is entirely out of the question to thus inspect all the private wells in a State as large as Illinois, we do the next best thing and require that we be furnished, on a suitable blank form, complete information of the wells and a sketch showing the surroundings. We will not send containers for the collection of samples until such information has been received, except at times to health officers whom we know will make proper inspections of the wells and supply the department with necessary information before the analysis has been completed and is ready to be reported.

Instruction sheets have been developed which not only explain in words how to collect samples to prevent contamination but contain illustrations along the margins opposite the text which show visually how to hold the sample bottles. In order to have the information about a well on a single sheet if possible, we ask that the sketch showing the well surroundings be made on the back of the blank form for recording the construction, etc., of the well. On the upper part of the back of this sheet a sample sketch is printed, and we have found that with this sample sketch as a guide the persons submitting the samples generally give fairly clearly all information desired.

We do not consider that we are giving much help to the owners of wells if we simply state, on the basis of the analyses, whether the wells are safe or not safe. Instead of such brief statements, if a particular analysis shows satisfactory results, but the information about the well and the sketch show that the well is subject to possible contamination, we call that fact to the attention of the owner and advise that the well, under the existing conditions, is not a safe source of water supply, regardless of the result of a single analysis. If the results are not satisfactory, we endeavor to state, on the basis of the information submitted about the well, the possible cause of the contamination, and, what is of most importance, we indicate how the well can be altered and improved to make it a safe source of water supply and at times recommend that the well be entirely abandoned and a new well, more properly constructed and located, installed.

We have found methods we have adopted in Illinois to be quite satisfactory, and we believe that we have been able to advise quite satisfactorily regarding private wells, even though the inspections are not made by members of the staff of the department, and we consider that we are giving the farmers and persons residing in rural communities, who must be dependent on private wells as sources of water supply, a service to which they are entitled if the department of health gives similar service regarding water supplies to persons living in cities.

Mr. C. N. Harrub. There is no doubt that the ideal way is for State health department representatives to collect and forward all water samples. This is impossible in some of our States on account of lack of personnel and lack of funds. In Tennessee we are obliged to rely on the local authorities to a considerable extent and sometimes on unskilled personnel of a water department to collect and send samples. Instructions are sent with each sterile bottle, telling how to collect and ship the sample, and wherever possible a demonstration in collecting, packing, and shipping is given before the local parties do any sampling by themselves.

Mr. DITTOE. I believe that the interpreter of analytical results should be thoroughly acquainted with local conditions, and that when reports are issued on samples alone that the statement should specifically mention that the sample of water is safe or not. Generally the collection of samples by local officials is unsatisfactory, and unless such local officials are trained in water-sampling procedure the results of analyses are of doubtful value. In order to be certain of the value of the findings, it is usually necessary for the State health department to collect as well as examine samples of water.

Mr. Dittoe told of the polluted well-water supply at Youngstown, Ohio, some time ago, and how the reporting of the purity of the water based on bacteriological results alone gave false security.

Mr. H. E. MILLER. The North Carolina statute requires that samples of water from public water supplies be submitted to the State laboratory of hygiene once a month for analysis. These samples are collected by the plant superintendent and in some instances by the local health officer. Water from private supplies is analyzed by the laboratory when submitted with a physician's certificate that the water is suspected as being injurious to public health. Additional samples are collected by representatives of the bureau. It has not been the practice in the past to send samples in ice. Iced containers are now being tried out by the laboratory. The result of this experience will probably be available by the time of the next conference.

AUTO TOURIST PROBLEM.

Mr. C. A. EMERSON, Jr. Many of you feel that the auto-tourist problem is one not worthy of notice by the Northern States, but consider for a moment that practically all of these tourists headed toward the Southern States pass through several other States, and that if they are planning to camp in the South after reaching their destination they undoubtedly will camp along the highways en route.

In Pennsylvania the forestry department and a number of the municipalities have provided free camping sites. We propose to examine the water supply and the toilet facilities at these sites. In fact we have already started on this work and generally find that the organizations providing the sites are willing and anxious to do what is necessary to make them safe for use.

Another type of camping site which I feel will be more troublesome is the tract of ground adjoining the roadside refreshment stand. T proprietor, hoping to sell supplies, welcomes overnight stops by the tourist, but if he were to provide water supply and toilet facilities as he should, it is probable that his profits would disappear.

PATENTED SEPTIC TANKS.

Mr. Dittoe spoke regarding the wide variety of patented septic tanks on the market and the unsatisfactory experiences which frequently result from use of such devices.

Mr. H. F. **Ferguson**. We have had the same experience in Illinois as in other States with the numerous "types" of septic tanks, for many of which exaggerated claims are made by the manufacturers or distributors. We have received frequent requests from residents of Illinois for comment on different makes or types, and in order to save time in answering such requests and also to state clearly our ideas on septic tanks, a bulletin was prepared entitled "Sewage Disposal for the Farm Home," which describes a simple septic tank and discusses what septic tanks will and will not do.

Mr. H. A. **Whittaker**. The attention of the conference is drawn to the fact that very little can be done to discourage manufacturers of sewage-treatment plants for private residences requesting official approval of the State boards and departments of health until health officials cease the practice of writing testimonials for these concerns which are used in their advertising material. Advertising material has reached the Minnesota State Board of Health containing a written testimonial over the signature of at least one of the State health officers. This is a subject on which a definite policy should be formulated by the conference.

Mr. F. C. **Dugan**. The Kentucky State Board of Health has given its approval to certain septic tanks on the market, but it has felt that these approvals should be withdrawn and only given for specific installations when plans were submitted.

It was also its opinion that the Conference of State Sanitary Engineers should make a study of all the various types of sewage disposal for private homes and report as to the best methods.

Mr. C. A. **Emerson**, Jr. In company with the other States, Pennsylvania has been favored by the vendors of septic tanks. We have not passed any regulations covering the use of such tanks and hope it will not be necessary, but we have written scores of letters to prospective purchasers who have asked our advice. We have told them the truth, stating, among other things, that the effluent from a septic tank is not "almost pure water which can be discharged into a roadside ditch," and also have tried to explain as to the proper length of tile which they will probably need.

Mr. Dittoe moved that the executive committee appoint a subcommittee to report on the fundamentals of proper chemical tanks, septic toilets, and nitrifying tanks and accessories. This motion was seconded and carried.

A motion was made by Mr. Ferguson, seconded, and carried that the corresponding secretary send out a letter ballot to each member for the election of two members of the executive committee who are to be chosen for the present year. The two members are to be elected from the following names which were placed in nomination: Messrs. Tisdale, Jackson, Miller, and Ferguson. The two men getting the highest votes will be declared elected.

The conference then adjourned at 12.30 p. m.

The CAMPAIGN AGAINST MALNUTRITION

Prepared by
ADVISORY COMMITTEE ON FOODS AND NUTRITION
of the
NATIONAL CHILD HEALTH COUNCIL
In cooperation with the
UNITED STATES PUBLIC HEALTH SERVICE

CONSTITUENT ORGANIZATIONS OF COUNCIL

American Child Health Association
American Red Cross
National Child Labor Committee
National Organization for Public Health Nursing
National Tuberculosis Association

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THE CAMPAIGN AGAINST MALNUTRITION.

Outline of Report.

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FOREWORD.[a]

Extent of Malnutrition.

MALNUTRITION is a term commonly used to describe the condition of a child who is not developing properly.[1] Studies made in various sections of the country indicate that there is a serious amount of malnutrition among the children of any area in which, for several years, there have not been systematic efforts to correct it. It is estimated by competent authorities that at least 20 per cent of the school children in our country are so much under average weight as to suggest the possibility that they are physically subnormal. Some persons believe that this estimate should be increased to 33 per cent or more. Malnutrition does not appear to be confined to any one race or class, for studies made in some cities have shown it to be more extensive in the families of the well to do than in those of more limited means.

Health Education as a Preventive Measure.

Intensive health supervision and corrective measures for this subnormal group are essential, but sound common sense points to the necessity of measures which will prevent many of the conditions causing malnutrition. A well-balanced piece of preventive work will include a thoroughgoing program of health education in the schools. It will also include energetic efforts to get parents to cooperate, reaching in this way, not only school children, but children under school age. Preventive work with the preschool child should be strongly emphasized, for it is during the early years of a child's life that it can be most effective.

Children of school age usually may be reached most easily by the school; to reach those under school age is more difficult and each community should give careful thought to the best methods of dealing with the preschool group.

Corrective measures should be used only for those children who, in the judgment of the physician, need more careful supervision than can be given in a general preventive program.

Better Training for Health and Nutrition Work.

If school-teachers are to do sound health work, it is essential that normal schools offer adequate training in health education, with appropriate emphasis on food in its relation to the growth of children and the influence of physical defects on nutrition. It is also important that medical and nursing schools shall give training in nutrition from the standpoint of preventive dietetics.

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[a] For list of members of Advisory Committee see p. 33.

[1] See appendix for statement giving a definition of malnutrition, standards for its identification, characteristic signs of improvement, and causes.

Home economics courses should put proper emphasis on nutrition as related to health. The supervisor of home economics in the school system is the logical person to plan and supervise the nutrition work in the schools, but, unfortunately, in many instances she has had too little training in the factors that contribute to malnutrition, or has too little time to give to the work. Her training should fit her for the work in its most modern aspect and, if necessary, her schedule should be reorganized so that her services may be available; her contacts should not be confined to a few girls in the cookery laboratory.

Suggestions Adaptable to Small and Large Cities.

The following suggestions are intended to suit conditions in a city of 25,000 to 30,000 inhabitants, because a community of this size often presents some of the serious urban problems found in larger places. Measures for such a city should be easily adapted for use in larger places and at the same time be useful and suggestive in smaller places, even in country districts. To be successful in rural communities, however, work must differ fundamentally in certain particulars from that done in towns or cities and, consequently, some suggestions concerning the conduct of nutrition work in country districts have been added.

Classes of Work Included.

1. Preventive nutrition work which should be a part of a program of health education for *all normal children*[1] of school age.
2. Corrective work for school children who are physically subnormal and in need of special attention.
3. Nutrition work with children under school age, both normal and subnormal.

Nutrition Work a Part of a Community Health Program.

Nutrition work should be conducted as a part of the general health work of the community and should in no case be promoted to the detriment of its other legitimate activities. If there is a general community health program such parts of the following plan may be incorporated as will not cause duplication. If there is no such program, then the one here presented, modified to suit each community, may be used as a guide and as an initial step leading up to a general health plan.

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[1] The general health education program has not been dealt with at any length because the National Child Health Council's Advisory Committee on Health Education has covered that subject in another report. See U. S. Bureau of Education, Health Studies No. 1, 1922

PRELIMINARY WORK IN THE COMMUNITY.

AROUSE COMMUNITY INTEREST IN THE MALNOURISHED CHILD.

THE community should be aroused to interest in the malnourished child. This may be done through forceful, well-qualified speakers; exhibits that show the amount and seriousness of malnutrition, and the results that have been accomplished through well-planned programs; articles in magazines; moving pictures; health plays, parades, pageants, and dramatizations; posters and window displays.

Speakers and exhibit material often may be obtained from the sources listed below and from those included in the appendix. As a rule speakers from such sources prefer to discuss child health in general, considering malnutrition as one phase of the subject.

State departments of health and public welfare.

Extension departments of State universities, agricultural colleges, and normal schools.

School authorities of city, county, and State.

Parent-teacher organizations.

Local or State tuberculosis or other health societies.

Other organizations. (See appendix.)

There are usually a number of local organizations whose interest may and, if possible, should be enlisted to sponsor the movement. For permanency, such work should be organized with agencies best fitted to develop it steadily and continuously. A list of some of these organizations includes:[3]

Board of health.
Medical society.
School board.
Red Cross chapter.
Tuberculosis association.
Parent-teacher association.
Women's clubs.
Infant-welfare and visiting nurse associations.
Association of university women.
Settlements and social welfare agencies.
Churches.
Libraries.
Chamber of commerce.
Rotary Club.
Kiwanis Club.
The Lions.
Civic leagues.
Citizen's associations.
Trade-unions.
The grange.

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[3] In smaller communities some of these organizations will not be found.

DEVELOP LOCAL LEADERSHIP FOR THE CAMPAIGN.

To be most effective the campaign should have the backing of some or all of the organizations listed in the preceding paragraph. A central committee might well be formed of their representatives. The interest and cooperation of prominent private individuals also should be enlisted wherever possible. The central committee should be an integral part of the public-health organization of the community, with whose program its work should be correlated.

USE EXISTING MACHINERY TO CARRY ON THE WORK.

If appropriate means for conducting the work already exist, it is important that such machinery be used. A thorough survey, therefore, should be made to determine what nutrition work is already being done, what more should be done, and what agencies and facilities in the locality can assist in the work or take entire charge of it. The local committee, or those who have the program in charge, should endeavor to secure the cooperation of all existing organizations, health officials, the local medical profession, or both, wherever possible. It should be borne in mind that nutrition work should always be a first step toward a complete health program or else a part of it.

The following agencies will be found useful in conducting corrective work:

Board of health.
Medical society.
Health centers (public or private).
Private child-welfare and health organizations.
Visiting or district nurse headquarters.
Maternity centers.
Infant-welfare stations or baby clinics.
Hospitals.
Out-patient clinics.
Dispensaries.
Hospital social service departments.
Red Cross chapter.
Settlements.
Day nurseries.
Orphan asylums.
Schools (public, parochial, or private).
Churches and Sunday schools.
Community centers.
Relief organizations.
Citizens associations.
Civic organizations.

MAKE A SURVEY TO DETERMINE THE SIZE OF THE PROBLEM.

Segregate the Malnourished Group.

Physical examinations.—A complete physical examination of all children by competent physicians is the most reliable basis for determining whether they are developing normally. This examination should include the weighing and measuring of each child as a first step. A complete physical examination once a year is desirable for all children, but essential if we are to know their condition and have an adequate basis for suggesting proper methods for the care of the underweight and physically unfit.

Weighing and measuring.—Where a lack of funds or facilities makes a complete examination for all children impossible, weighing and measuring them will afford a means of selecting the group which will contain the large proportion of malnourished children. Those found to be 10 per cent or more below or 20 per cent or more over the average weight for height and age may be taken as a group which should be examined to determine whether they need further attention. This will not reveal all undernourished children, but it will serve as a starting point.[4]

Study the Causes of Malnutrition.[5]

The causes of malnutrition must be clearly understood by those who plan and carry out the survey to determine the extent of malnutrition in the community as well as by those who work with the malnourished group after it has been segregated.

It is important not only to know how the habits, condition, and immediate environment of the individual child affect the situation, but also what conditions in the community contribute to the problem. Some of the points mentioned below may be considered in the survey itself, particularly those regarding community conditions.

Physical defects, habits, and immediate environment affecting the nutrition of the individual child.—A large proportion of underweight children have physical defects of some kind and will not gain until these defects have been corrected. Often correction of defects is all that is necessary to give a child a chance to develop normally. Nasopharyngeal obstructions are a factor of the greatest influence in causing malnutrition, since they prevent proper breathing and intake of oxygen. Carious teeth, which are found in a large number of cases, are a good breeding place for germs, prevent proper mastication, and thus hinder good nutrition. These two classes of defects are mentioned because they are very common. There are, of course, others more serious.

Overfatigue is a cause of malnutrition which is often difficult to recognize, as a very moderate amount of exercise will have an undesirable effect on some children. A child that grows rapidly will often, even when nutrition is apparently good, be apt to experience exhaustion after limited physical exercise. Such exhaustion often interferes with school progress. Its most common manifestation is lack of concentration and inability to apply the mind to any one thing for more than a few minutes at a time except under special stimulus. Exhaustion is frequently due to too intense or exacting a daily program for the child, too heavy school work, too many outside classes or lessons, too much physical exercise, especially too much strenuous play, too many "movies," and too much nervous excitement. (See p. 18 for suggestions regarding rest.)

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[4] See appendix for statement concerning malnutrition, standards for its identification, etc.

[5] See "Points to be borne in mind by those in charge of nutrition work" for further discussion of the causes, page 17.

Improper diet and faulty food and health habits are very large factors in the production of the most common forms of malnutrition. They are often due to ignorance and perhaps even more often to a lack of home discipline, which is one of the main indirect factors causing malnutrition. Poverty also makes it impossible to obtain an adequate diet in some cases. In the appendix there is a list of some good food and health habits which should be observed. If these habits are to become a part of the child's daily life, the education and cooperation of parents must be assured.

Children should be taught to breathe, stand, sit, and walk properly. The body can not utilize food without air for oxidation, and an erect, easy carriage is necessary not only to the free play of the lungs but to the proper position and functioning of the larger organs in the trunk.

Faulty posture or incorrect body mechanics is associated with fatigue and is one of the conditions most commonly found in malnourished children. Faulty posture, fatigue, and malnutrition form a vicious circle and react one upon the other. They should all be corrected to obtain the best results. Faulty posture may be helped by corrective exercises, carefully supervised by specially trained instructors, under the direction of an orthopedist. In prescribing exercises as an aid to the correction of faulty posture the fullest consideration should be given the fact that the undernourished muscles are very susceptible to fatigue and that this militates against upbuilding. Therefore muscular exercises should be prescribed and directed with extreme caution and with careful study of both their immediate and remote effects.

All orthopedic defects should be recorded in the course of the physical examination, and appropriate steps should be taken to obtain their correction.

In many cases children fail to gain because of conditions in the home which are beyond their control. It has been found that fear of punishment and constant nagging and scolding have sometimes caused failure to gain. Where this cause has been corrected, some remarkable gains have been noted.

Many homes have inadequate and unsatisfactory sleeping accommodations, and children fail to get enough sleep or fresh air at night. There may be insufficient food or an ill-balanced diet because of low income or conditions that the family can not correct. In such cases cooperation with some social agency is essential if gains are to be permanent.

General community conditions which may contribute to malnutrition.—The nutrition program can not be fully effective unless consideration is given to such factors as the following:

Housing conditions.
Sanitary conditions in school buildings.
Atmospheric contamination by smoke or other substances.
Availability of pure water.
Facilities and opportunities for play and recreation.
Employment of women and children in industry and overwork at home.
Market conditions:
  1. Food inspection and control.
  2. Availability of certain foods, especially milk and leafy vegetables.
  3. High prices.
Medical and dental service.
Organization of school programs so that pupils may not be overtaxed, and a proper relation between work and rest may be maintained.

All of these things should be considered not merely because of their effect on nutrition, but because of their serious bearing on the health of the entire community. Those engaged in the health or nutrition program should stimulate the proper agencies to eliminate bad conditions, but failure to effect improvement in this direction should not be allowed to discourage attempts to carry out the work. If based on sound principles this will justify itself in communities where conditions are far from desirable. Some of the appropriate agencies to be interested in improving conditions are: Private health organizations, local health departments, boards of education, chambers of commerce, consumers' leagues, women's clubs, citizens' associations, and housing commissions. Such bodies as the United States Bureau of Markets, the State labor bureau, and State departments or boards of agriculture often may be of assistance.

OBTAIN PUBLICITY REGARDING MALNUTRITION IN THE COMMUNITY.

It is important that publicity be obtained regarding the results of physical examinations or the weighing and measuring campaign. This may be effective in arousing the community to action. Comparisons of local conditions with those found in other cities often are valuable and stimulating. A special subcommittee should be appointed to deal with this question, and the editor of the local paper might well be made its chairman.

NUTRITION WORK IN THE SCHOOL HEALTH PROGRAM.

IN the foreword to this report mention was made of the prime necessity for combating malnutrition by preventive measures, one of the most effective of which is a thoroughgoing program of health education in the schools, with proper attention to diet and nutrition. As stated previously, a program dealing specifically with health education has been prepared by the advisory committee on health education of the National Child Health Council, and only a summary is included here for the sake of suggesting a well-rounded program. For a fuller discussion of school health work the reader is referred to School Health Studies No. 1, United States Bureau of Education, 1922.

ORGANIZATION OF NUTRITION WORK FOR NORMAL CHILDREN IN THE SCHOOLS.

Every child should have a complete physical examination, and all defects discovered in the course of this should be corrected promptly. Health education should permeate the entire school curriculum and include among other things information regarding food and correct food habits. Such information may be incorporated in lessons on reading, writing, English, history, geography, drawing, biology, and mathematics, as this is a most effective way to bring about a constant natural absorption of health truths.

More direct methods of teaching good nutrition to normal children also should be a part of the regular school health program. Work of this kind will be found of greater value than mere informational material and should be under the direction of a well-trained supervisor of nutrition on the school staff.

Efficiency and economy make it advisable to enlist the services of the home economics teachers already employed in the school system to supervise instruction regarding nutrition. To be successful, however, they must have (*a*) an adequate general training in health subjects, (*b*) a knowledge of modern nutritional subjects with especial emphasis on methods of controlling malnutrition, (*c*) time for effective supervision of the nutrition program, and (*d*) the advice and guidance of a physician, preferably the school physician. Where present supervisors lack training which will give them the desired viewpoint, they should be expected to obtain it and should be given the time necessary to organize the work. On page 12 will be found suggestions for obtaining nutritional guidance on a part-time or consultant basis, where it is not possible to obtain it on a full-time basis. If the school system is unable to pay for such services, some agency outside the schools may finance the work, but in any case the nutrition worker in the schools should be considered a regular member of the faculty. The nutrition worker should give to the class room teachers a graded course of instruction concerning food and food habits. This instruction should be simple enough to be repeated to the children, who should receive it, in turn, from the classroom teacher. The nutrition worker should, for purposes of demonstration, teach the children herself occasionally, giving individual attention to the children in need of it. This course of instruction in nutrition should be correlated with the instruction in the other aspects of hygiene which may be given by grade teachers and by other health workers, such as the doctor, the nurse, and the teacher of physical training.

THE PLACE OF THE MIDDAY LUNCH IN THE SCHOOL HEALTH PROGRAM.[6]

The problem of malnutrition can by no means be solved by the midday meal at school, but this feature of the program is justified if nothing more is accomplished than to provide an adequate meal for children who find it impossible to get a good midday luncheon or dinner at home. When the school lunch is used as a means of influencing the food eaten at home its value is greatly increased. If the lunch is carefully planned, prepared, and served there is an excellent opportunity for:

(1) Teaching what foods are necessary for health, and how these foods must be used to insure good results.

(2) Helping to establish a taste for the right foods and influencing children to eat them at home as well as at school.

(3) Interesting children to eat unfamiliar foods which they refuse to eat at home.

(4) Establishing habits of cleanliness, good table manners, and consideration for those who cook and serve the food.

(5) Instructing mothers in the correct feeding of children.[7]

The school lunch may serve as a practical demonstration to reinforce the teaching of nutrition in the classroom. The facts may be driven home by such remarks as "You see, we serve milk or cocoa instead of coffee," and "We serve vegetables because it is cheaper and better to get vitamines, iron, calcium, and other things needed in the body in food than in medicines." Food facts may be taught through talks, stories, and posters. Literature may be obtained from some of the agencies listed in the appendix.

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[6] Lunches to be paid for by the children wherever possible.

[7] Mothers may be invited to the lunch room to taste the kinds of food children should be taught to eat and may be taught how to make the children eat the things they should.

REQUIREMENTS ESSENTIAL TO THE SUCCESS OF THE SCHOOL LUNCH.

There are three requirements which are essential to the success of the school lunch: (1) The teacher must have a knowledge of food in its relation to health and a will to teach the child proper food and health habits; (2) school authorities, parents, and public-spirited citizens must see that the school lunch is efficiently managed and that the opportunities which it offers for educational and social improvement are fully utilized; and (3) the financial control of the lunch should be vested in the school board, which should provide facilities and equipment, pay all employees, and control receipts and expenditures. In some cases money to finance the lunch has been furnished by local organizations or philanthropic individuals; funds also have been raised through school functions, and in some instances food has been contributed by the pupils. These methods vary in degree of satisfaction, but no method is so satisfactory as financial control by the school board. This, fortunately, has been legalized by several States.

Whatever method of financing may be adopted, it should be emphasized that the school lunch is not a plan for the free feeding of children, in school or out, but a measure of value in the school health program. Comparatively few children will be found in any community who are unable to pay for the lunch. These may be cared for quietly without stigma through the philanthropic organizations of the community—the Junior Red Cross, the tuberculosis association, the parent-teacher associations, or women's clubs. In some cases those who can not pay the entire cost can pay part, and this is desirable, for the payment of even a few pennies a week serves to retain self-respect and lessen tendencies toward pauperization.

THE MIDMORNING AND MIDAFTERNOON LUNCH.

While there is little conclusive evidence, based upon careful study, as to the results of midmorning lunches, general reports received from supporters of the movement attest their beneficial effect.

The reasons in favor of the midmorning lunch are (1) that many school children, particularly those in the lower grades and those who are below par physically, do better on four meals than on three meals a day, and (2) that many children, especially those of working families, eat their breakfast at an early hour and have to go too long without food if they do not have anything to eat between breakfast and the noon recess.

On the other hand, some assert that the midmorning lunch has been supplied without proper social safeguards, in at least some instances, and has served to decrease the parent's sense of responsibility for providing adequate food at home. In all cases school authorities should assure themselves that the lunch is not being made an excuse by parents for cutting off a part of the child's food at home, and where this is suspected to be the case, careful follow-up work should be done.

Some pediatrists advise discrimination in the selection of children to receive midmorning lunches, so that those not in need of extra nourishment will not receive it and so that the food is not too much a duplication of that received at home. It is important that the judgment of the school medical examiner, where available, should be had as to the extent to which such lunches should be provided. This is particularly true in cases where it is proposed to provide both midmorning and midafternoon lunches for children who are underweight or show other signs of malnutrition. The weight of opinion is in favor of the midmorning lunch under proper safeguards, particularly for children who are below par. Unfortunately, both its value and the possible disadvantages of its use without proper discrimination are too largely subjects of opinion.

FACILITIES AND METHODS FOR CORRECTIVE WORK.

CENTERS FOR SERVICE AND NECESSARY EQUIPMENT.

A GOOD location is essential. Some questions to be considered in deciding upon the location of centers are:

Where may mothers and fathers as well as children be reached most readily?
Where may best cooperation be obtained?
What place affords best facilities for work and is freest from interruptions?
Where will the child get a positive rather than a negative idea of health?

Hospitals, clinics, and dispensaries where medical supervision is available generally should be reserved for cases of organic disease and severe malnutrition. Ordinarily it is not desirable to bring children to places associated with disease for class work. Certain "Well Baby Clinics," orthopedic and other hospitals, in which children stay over long periods of time, form an exception to this rule, and hospitals may do very useful work in holding health or nutrition classes for convalescent children.

The following places constitute possible locations for centers:

Schools.[8]
Health centers.
Municipal or county rest rooms.
Farmers' headquarters.
Day nurseries.
Settlements, churches, etc.
Public-health nursing offices.

The following places will be found particularly useful for the younger children:

Infant-welfare stations.
Maternity centers.
Milk stations.
Kindergartens and settlements.
Day nurseries.

Facilities and equipment.[9]—A well-lighted, well-ventilated, clean, quiet room, where the work will be free from interruptions, is needed.

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[8] The school building is almost always the best place for work with the school child and should be used if available. Ideally, every school building should have a well-equipped, well-lighted room for the use of school physicians and nurses. If it can be obtained at a time when the work will not be interrupted, this room, or the home economics classroom, may be used for the conduct of nutrition classes.

[9] It should be understood that the facilities and equipment outlined are desirable for efficient operation. While excellent work has been done without some of these facilities and without certain parts of this equipment, anything less desirable places the nutrition worker at a disadvantage and means that the work must be conducted under a handicap.

This room should be easily accessible and not above the second floor, unless an elevator is available. It should be equipped with running water and toilet facilities, and should have wall space sufficient for permanent exhibits and individual charts for the children in the nutrition classes.

The following equipment will be needed:

Essential—

Scales (standard rod scales) and, if needed, an infant scale.

Measuring rod (a substantial one on wall as well as on scale advisable). Two yardsticks tacked against a flat wall are preferable to tape lines, which stretch under continuous use unless pasted to a flat measuring board.[10]

Low benches and little chairs for children and chairs for parents.

Tables.

Screens or curtains.

Facilities for hanging wraps (wraps should be hung so as not to touch each other).

Facilities for making and hanging charts.

Such additional equipment as the physician may specify.

Desirable—

A blackboard for class instruction.

Cases for food exhibits.

A file for records and large charts.

A gas stove, or electric plate, and oven; and such cooking utensils as simple demonstrations may necessitate.

STAFF REQUIRED.

Medical service.—Cases of severe malnutrition require long, close, continued medical supervision, and where nutrition classes are held the physician should visit them regularly. Medical services preferably should be paid for and may be secured on a part-time basis. Physicians should give physical examinations to all undernourished children, reexamine children who do not improve, and give consultation and supervisory service both to individuals and to health and nutrition classes.

Nutritional supervision.—In an extensive piece of work there should be employed on full-time a nutrition worker[11] who has had special training in foods as related to nutrition, and growth of children, and food economics. This worker should have a thorough understanding of the importance of physical defects and other individual or environmental causes of malnutrition; and should possess marked teaching ability, as one of the most important parts of the work is that done in instructing nurses and other workers in normal nutrition.

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[10] To determine height a square block should be placed on the top of the child's head and against the measure. Such a block is preferable to a ruler or any thinner object, which invariably slants more or less

[11] See standards recommended by the Advisory Committee on Foods and Nutrition of the National Child Health Council.

Where it is not feasible to employ such a specialist on full-time at each center or station, one of several methods may be adopted:

(*a*) Service of one worker may be made available for several stations combined.

(*b*) In smaller places such services may be provided on a cooperative basis with educational institutions, local hospitals, or health agencies.

(*c*) In country districts guidance may be obtained from larger communities near by, or by an arrangement with the county home demonstration agent.

In some cases several towns have combined in the employment of such a supervisor.

A specialist of this kind should visit schools (where there is no supervisor of home economics in the school system) and stations, train teachers, nurses, and other workers in normal nutrition and food economics, and give general consultation service in the solution of difficult nutritional problems.

Nursing service.—Where nutrition work is under the general supervision of a trained nutrition worker, who has sufficient time or assistance for class work and follow-up work in cases involving dietary problems, nurses may confine their follow-up work to that necessary to obtain the correction of physical defects, see that patients receive proper care after correction, watch children for symptoms of disease, and give individual instruction regarding the observance of good health habits. They should also share in the teaching of health habits and hygiene in the nutrition classes and to the teachers.

Where there is no nutrition worker attached to the staff, it is very important that nurses, in carrying on such nutrition activities as are practicable in view of their training, should supplement their knowledge of foods and food habits and secure assistance in solving food problems from some person well trained in nutrition, such as the local home economics teacher or farm bureau representative.

Nutrition field workers.—Where the budget makes it possible, there should be nutrition field workers to go into homes and help mothers deal with special dietary problems which are beyond the experience of the average field health worker who has not had special training in nutrition. As in the case of the nutrition supervisor, such a person should be adequately prepared from health and social service standpoint. She also should teach nutrition classes. In an extensive program, where there are many children to be handled in classes, one nutrition field worker should be assigned to class work. The personality and training of the class teacher are very important, for unless she is able to enlist the interest of the children and make her teaching forceful, she can not be successful.

Auxiliaries.—All suitable agencies in the community should cooperate in carrying on the nutrition program, so that expense and duplication may be avoided and the work may have the benefit of varying points of view. Some agencies that may not have facilities for assisting in the work may be important factors in financing and popularizing it.

Volunteers.—Volunteers may be chosen from cooperating organizations, especially from women's clubs, parent-teacher associations, and associations of collegiate alumnæ. Service by volunteers is always valuable, as it tends to extend interest. Volunteers may be trained to take children to dispensaries, to keep records, to help with regular weekly weighings, to make charts, and assist in other ways. This increases the amount of specialized work which may be done by more highly trained persons. Volunteers, however, should take special training, through nutrition conferences or institutes, to be of the most effective service.

METHODS OF WORK.

In preventing malnutrition there should be a general health program to educate the whole community—fathers, mothers, and children. Parents may be reached through literature, lectures, entertainments, general propaganda, clinics, and home visits. Children may be reached through schools, clubs, entertainments, and classes, and in other ways.

Work with the Child Under School Age.

Special emphasis should be placed upon work with children under school age, so that they may develop normally. If proper prenatal care could be given and if the habits of children could be regulated from birth to school age, the health work now necessary in schools might be greatly reduced.

Mothers should be urged to bring the babies and younger children to health centers at stated intervals for examination and advice. They may be encouraged to do this by visits to their homes and in general meetings. At first mothers have to be urged to come to the station and often must be accompanied. When the benefit to their children is made evident, however, they will seek help, and home visits may be made less frequently.

The class methods employed for children of school age must be modified if group instruction is to be successfully attempted with preschool children. In some nursery schools health education has been successfully given in connection with lunches, carefully planned and supervised, and even with very young children the influence of the group has proved valuable in cultivating the habit of taking proper food. In some cases successful classes have been formed for mothers and children, the chief emphasis being put on habit formation. Some nutrition workers have found it valuable to conduct a part of the work only in the presence of the children. In these cases facts that will hold the interest of the children are discussed while they are in the class; after they are dismissed their mothers are instructed regarding their diet and other important matters.

Mothers should always accompany young children to the class, for the main benefit from the work results in the instruction which they receive in the presence of the children. Whatever class methods may be employed, the importance of home visiting by the nurse or nutrition field worker (where one is employed) must not be overlooked.

The importance of thorough and competent medical supervision as a foundation for nutrition work is particularly apparent with the preschool group. The disclosure of defects at this age, with a careful follow-up for their correction, gives the child a better chance to start his school career unhampered by physical disabilities.

Work with the Malnourished Child of School Age.

For permanent good health and resistance to disease it is necessary to practice good health habits, and the importance of general health education and health supervision for all school children has already been discussed. They should be given general instruction in health habits and food values, and every possible method should be used to stimulate them to follow the health program. Children below weight, but with no physical defects, those whose defects have been remedied, or those who are temporarily underweight from illness will usually come up rapidly under such general instruction.

Children should have, upon school entrance, a complete health examination by trained school physicians, which will test and record their physical and mental conditions and adjustments. They should be examined annually thereafter, or at least once in every two or three years. Those below par should be reexamined with such frequency as their particular conditions indicate, and those who are retarded in school progress should be reexamined carefully to determine whether their slow progress is due to discoverable and remediable health defects.

In actual practice the frequency of examinations will depend upon the financial resources of the school. In many communities health examinations are not now given to any of the children. These communities should be made to realize their importance, and in such places earnest efforts should be made to have examined at least those children who are underweight or who show other signs of malnutrition.

If necessary in the judgment of the physician, these children may be referred to the nutrition or health classes for intensive work. To gain interest and cooperation it is well to have one or both parents and the classroom teacher present at the examination.

Correction of Physical Defects.

After physical defects have been noted, children should be referred to the family physician for their correction. Those who are unable to pay should be given dispensary or hospital service, dental service, or care by an oculist provided by the community.

Class Methods.

The following discussion of class methods is not designed to furnish guidance as to the ways and means of interesting and stimulating children, whose cooperation is essential to the effective conduct of the work. Methods of obtaining such cooperation have been ably dealt with in publications issued by such agencies as the United States Bureau of Education; Bureau of Educational Experiments, New York, N. Y.; the Child Health Organization of America; Teachers' College of Columbia University; the Elizabeth McCormick Memorial Fund; Nutrition Clinics for Delicate Children; and some others included in the list appended to this report.

Even at the risk of repetition, it should be emphasized that in conducting nutrition classes it is necessary to have (*a*) thoroughgoing health examinations and medical supervision for all children; (*b*) adequate medical and nursing service for the correction of physical defects and bad health conditions; and (*c*) advice and supervision as to foods and methods of food preparation by a thoroughly trained nutrition worker, whether on a full-time, part-time, or a consultant basis.

Physical defects, including carious teeth, should be corrected, if possible, before much time is spent in trying to make children gain by readjusting health habits. Good health habits should certainly be established as soon as possible, but there is often a useless expenditure of time and energy in attributing failure to gain to bad habits when there is some underlying physical obstruction.[12] It is well to secure the cooperation of the parents at the outset, through home visits if necessary, and mothers should be urged to attend the class.

A worker in charge of nutrition classes can care for approximately 100 children in classes of 20 each for intensive work. With this number some clerical help will be required; and also assistance in home visiting. A nutrition worker may handle larger groups in schools where instruction regarding nutrition is given as a part of the general health program for all school children, in correlation with instruction in other aspects of hygiene given by grade teachers and special health workers, such as the physician and nurse.

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[12] Some physicians believe that children with enlarged tonsils should not be operated upon until an attempt has been made to build them up physically.

The class should meet each week and children should be weighed weekly, after coats, sweaters, and shoes have been removed. Heights should be taken at the first lesson and retaken at least every three months. Weights should be recorded on weight charts, so that gains and losses may be discussed with mothers and children. Children should be stimulated to develop good food and health habits. The actual class work should not last over 20 to 30 minutes.

Devices for stimulating interest are: Cards [13] (which may be illustrated), giving actual weight of a child and the proper weight for height and age; different-colored stars for gains or losses; games, stories, and plays; the making of pictures, posters, or food exhibits; placing children on parole for a period of from three to six months; appropriate exercises, with presentation of some sort of certificate when the children have shown that they are following the rules of health and have made satisfactory gains. It is most important that such exercises or certificates shall not give the children the impression that they have graduated from the observance of health habits. There is a real danger if they are not used as an incentive to further progress as well as a recognition of past progress. Children should be watched for 6 months to one year after graduation to see that they continue to gain normally. Due weight should be given to seasonal variations. In the spring and fall some losses and gains may be attributed to changes in clothing.

If classes are included as a part of the school program, every effort should be made to hold them during school hours, as the work then has the sanction of the school, and both children and teachers have a better attitude toward it. If this is impossible, the class should meet after school, either in the school building or at some place near by.

Home Instruction or Intensive Work.

The necessity for home visiting is vital, whether we deal with children individually or in groups, or deal with their mothers at the place where the class is held. Often it is only by a visit that the cause for unsatisfactory progress may be discovered. The visitor may work with the mother to show her how to correct unfavorable conditions and to encourage her in matters of child discipline. Instruction regarding the relation of physical defects to malnutrition and the necessity for good health habits, proper food, marketing, and even food preparation may be necessary. Portable scales may be used for weighing small children. Wherever it is possible to see the father of the family, educational work may be done at a point much needed.

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[13] When these cards are given to the children at appropriate intervals they may include one health habit and a recipe for a desirable food.

Relative Value of Group and Intensive Methods.

A combination of group work and home instruction is usually most satisfactory. Their respective points of advantage are:

The group method.—A larger number of children may be reached when handled in groups and the group spirit makes it possible to interest some children who would be reached with much more difficulty individually. Group work lessons the amount of necessary home visiting (which is expensive) and admits an easier appeal to community interest. On the other hand, individual and home problems are not so intimately known when group work alone is used, and causes of lack of progress are often overlooked. It is well to remember that group work is not generally successful unless the group consists of children of the same age.

Individual or home work.—Home visits give more lasting results than any other method and are essential for effective work with children of preschool age as they are too young to receive much benefit by group instruction. They are also essential for effective work with school children who are held back in their progress. They are especially effective in hastening the progress of children who are handled in groups. They are often essential to prevent parents from getting from children wrong impressions about the work and in correcting the misrepresentation of home conditions by the children. The expense of the intensive method is greater than that of the group method, but it can not be dispensed with if thoroughly successful work is to be done.

Points to be Borne in Mind by Those in Charge of Corrective Work, Whether Work Is Being Done in Groups or Individually.

Under the statement concerning the causes of malnutrition on page 3 the importance of correcting physical defects, of adequate sleep and rest, and the observance of good food and health habits were discussed. It is believed that the following suggestions will be useful in emphasizing these points:

Lack of home discipline.—Lack of home discipline is one of the most important factors in causing malnutrition, and mothers must be impressed with the importance of training children to form good food and health habits. Parents must be brought to see the part they can play in the program by helping children to form good health habits and by providing them with proper food.

Rest for the physically subnormal child.—It is important not only that children have long hours of sleep at night, with bedroom windows open, but that their daily program is not too strenuous. The underweight child should be relieved from all strain until he is in normal health. Two daily rest periods, one in the middle of the morning and one in the afternoon, are a great help in lessening overfatigue.[14] It is preferable that the child actually rest, sleep if possible, from 20 minutes to one hour, according to the seriousness of the condition. If it is not possible to induce the child to sleep he should lie down quietly. If necessary, a child may be read to for a few days until the resting habit is formed. The habit of resting completely is as important as eating correctly. The child should be required to bring to the class a record regarding meal times, the time spent at meals, hours for going to bed and getting up, hours spent at school, hours on home lessons, outside classes, music, dancing, languages, drawing, clubs, movies, etc.

Improper food and food habits.—Children should be instructed regarding proper food and good food habits, as they can then analyze their own food habits and correct them if required. As the follow-up worker makes her visits, she may discover what is wrong with the diet and suggest changes. The child may be asked to bring to the second meeting of the nutrition class a record of what he eats (including food eaten between meals) for two or three days, or, better still, for a week. In the light of such information, each child may be helped individually, and information of this kind should be obtained as often as found advisable. Some undernourished children often gain more rapidly on five smaller meals a day than on three heavy meals. To meet this condition, it may be advisable to give mid-morning and mid-afternoon lunches. Such lunches should be given, however, only upon the advice of a physician.

Faulty health habits.—The list of a child's daily activities perhaps will indicate which of his habits are faulty, and he can be stimulated in a dozen picturesque ways to rest, brush his teeth regularly, wash his hands before every meal, take frequent baths, go to the toilet regularly, etc. (See literature prepared by the United States Bureau of Education, American Child Health Association, and other organizations shown in the list printed in appendix.)

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[14] Rest periods for subnormal children should be secured in the school where possible, and cots and blankets should be available for this purpose. If cots are not available, the child can rest with the blanket spread on the floor, newspapers being placed under it to avoid dust. Under some conditions it will be found advisable to excuse children from school and give them time to rest at home in the middle of the day, returning to school for the afternoon session. Some authorities believe that it is advisable to have a thin pillow placed under the shoulder blades of the child when resting (not under his head) for the correction of faulty posture common to malnourished children. Such a pillow, however, should be extremely thin, if used.

CHARTS AND RECORDS; ANALYSIS AND SUMMARY OF RESULTS.

It will be necessary to have, besides individual charts to show the progress of each child, charts for the class, which will show the average gain of the group.

The individual charts should be as attractive as possible, and, as they are to be hung on the wall, should be large enough to be seen easily by everybody in the room. They should carry some indication of the average weight of a child of given height and age. This may be a dot or a short line one-half inch long put in once every two or three months. It will vary as the height changes. On the chart should be shown the gain or loss each week or each month as the child is weighed. Charts should furnish accurate information regarding all factors governing the weight of the child.

Efforts should be made to record the same essential information in all parts of the country. If a standard record form could be adopted and used throughout the country or even in an entire community, it would help in the collection of valuable statistical data. In devising records, care should be taken to eliminate unnecessary information. Records may be so elaborate as to constitute a menace to good work, but must be carefully kept and provide adequate information if sound conclusions are to be drawn.

Points to be recorded relate to:

Social and family history.
Medical history.
Physical examination.
Notes of defects corrected; home visits made.
Physical improvement, including gain in weight.
Food and health habits.

These points may be put on one record form or separate forms may be used.

Records for groups should be studied and the results should be summarized so as to set forth the facts concerning such things as:

Factors contributing to malnutrition.
Defects corrected.
Causes of failure to improve.
Extent of family cooperation.
Improvement in food and health habits.
Modifications in children's school and home programs.
Amount of weight increase and improvement in posture, color, muscular development, mental and physical activity, etc.
Length of time required to obtain favorable results.

Samples of charts and records now being used may be obtained from the New York County Chapter, American Red Cross, 598 Madison Avenue, New York, N. Y.; American Child Health Association, 370 Seventh Avenue, New York, N. Y.; Elizabeth McCormick Memorial Fund, 848 North Dearborn Street, Chicago, Ill.; Dietetic Bureau, 376 Boylston Street, Boston, Mass.; Nutrition Clinics for Delicate Children, 44 Dwight Street, Boston, Mass.

MEANS OF MAINTAINING THE WORK.

INTEREST MAY BE SUSTAINED BY:

(*a*) Printed reports, brief but interesting, illustrated with individual and group charts, photographs, etc.

(*b*) Wide newspaper comment, articles in magazines, school papers, etc. (Workers should be encouraged to make full notes and to write up interesting items and stories to be used for publicity.)

(*c*) Programs before local organizations, clubs, mothers' meetings, etc., with graphic exhibits of work and outline of future needs.

(*d*) Group competitions in which a banner or pennant is given to the class or school making signal progress.

COST OF THE WORK.

The nutrition class, representing, as it does, careful, intensive work with individuals, is necessarily a relatively expensive method of fighting malnutrition and should be reserved for children assigned to it as the result of medical examination.

In the report of the National Child Health Council's Advisory Committee on Health Education an estimate of the cost of a school health program in a town of 25,000 to 30,000 people may be found. but sufficient data are not available to admit an authoritative statement as to the average cost per child of nutrition class work. This depends, of course, upon the progress made by the child and the length of time he stays in the class, the number of home visits which are necessary, and many other matters. This matter is one which needs careful study.

The apparent cost of the work will, to a great extent, depend upon the facilities already possessed by the community which can be used to carry it on. The use of existing personnel or facilities for additional work, however, is a matter for earnest consideration. It is often found, for example, that the school physician is already overburdened with the regular work of medical inspection or perhaps simply with the control of communicable disease; that the home economics supervisor and the school nurse are overworked or need supplemental training for nutrition work. In such cases one of the first objectives should be to see that the staff in the schools is made more adequate.

Many physicians are willing to give volunteer service, but so much is already demanded in this line that, if possible, it is only fair to pay for such work. In certain communities half the time of a younger man interested in nutrition and preventive work may be secured from $150 to $200 a month.

The salaries of field nutrition workers range from $100 for an assistant worker, just graduated from her training in food economics or nutrition, to $125 or $150 a month for more experienced workers. For a supervisor of the kind mentioned on page 11 it may be necessary to pay from $150 to $250 per month. Provision should be made for salary increases as the work progresses.

Most communities of the size under consideration already possess public-health nurses, hospitals, and dispensaries and some have health centers. Where these are inadequate they should be developed, but this should be done as part of a general community health program and not be considered a legitimate charge against the nutrition program. The parents of a majority of children will be found able to pay reasonable fees for the correction of physical defects, and, almost without exception, they are able to pay for the food served in the schools.

It may be necessary for some individual or private organization to take the lead in financing the physician and the first nutrition worker or workers. In several communities the women's clubs or parent-teacher associations have paid the salary of the first nutrition worker, while the Junior Red Cross has often paid for the milk which a few children could not afford to buy. In some cases the Red Cross has financed the salary of a nutrition worker until the work could prove its value.

Often some public-spirited individuals or a private organization must finance the experimental work necessary to prove the wisdom of a new idea, but such a service as that for the malnourished child belongs so essentially to the community at large that the cost of the work should eventually be borne by the public. While it is true that at present few of our public agencies are equipped to carry on this educational work or have standards and ideals equal to those of the private agencies, the aim should be to make public agencies truly serviceable in the health program.

POINTS TO BE CONSIDERED IN RURAL DISTRICTS.

IN the rural sections of the country malnutrition must be fought largely by means of a program of general health education in the schools. If this is to be effective, however, efforts must be made to arouse the interest of rural communities and to see that rural teachers are given more adequate preparation for health training and instruction. In some communities progress has been made by employing county supervisors of health education or nutrition to meet the grade teachers periodically and train them to give effective instruction regarding health and nutrition. After such educational work has been done, however, there will still be need for intensive work in the nutrition class, and conditions in the rural community give rise to many perplexing problems as to the practicability of segregating the malnourished group, conducting classes, correcting defects, obtaining medical supervision, and other matters.

AROUSING AND SUSTAINING INTEREST.

Movements which have been approved by national or State agencies have much more standing in the average rural community than those not so indorsed. In opening the campaign in rural districts it will be well, therefore, to procure in advance and have ready for distribution letters of indorsement from all State educational agencies which deal with health education and nutrition work. Literature issued by national organizations, showing the widespread character of nutrition work and the benefits which have followed it in various parts of the country, also will be of value. In stressing the extent of malnutrition in the early stages, State and national figures should be given instead of local data. In discussing the local situation it is always better to present the positive rather than the negative view showing State, county, and community achievements in health work, stressing the advantages to health which should accrue from rural life and thus inspiring the community to realize its best possibilities.

In starting the work a committee should be formed of individuals whose civic interests will make them efficient allies. The persons who naturally would be members of such a committee are the local physicians, county superintendent of schools, teachers, the home demonstration agent, and the public-health nurse (whether employed by the county tuberculosis association or Red Cross chapter). Representatives of the community center, social organizations, such as the grange, farm bureau, farmers' clubs, and religious organizations, should be on the committee. The rural editor or reporter should be made an active cooperator in the work as he can give valuable assistance in obtaining publicity, and the aid of the librarian and all public-spirited citizens should be sought. The chairman of the central committee should be primarily an individual well known and respected in the community.

Exhibits may be held in the village store, at community, county or State fairs, poultry or other shows, school entertainments, rural teachers' institutes, and at meetings of the grange, farm bureau, or other social, religious, or educational organizations.

It is valuable to obtain speakers from a distance, but local talent should not be ignored. Local physicians, nutrition workers, nurses, ministers, and resident representatives of any interested county, State, or national agency are often able to make valuable contributions, and it is frequently possible to find in the community a married woman, who has been trained in home economics or nursing, who will help with the campaign.

After the community has been aroused to an appreciation of the necessity of the work, a weighing and measuring campaign should be instituted and effort should be made to have at least all children 10 per cent or more below the average weight given a thorough physical examination and to see that all discovered defects are promptly corrected.

When the work has been in progress for a sufficient length of time, achievement meetings, held in the school or other center, are valuable in sustaining interest. The school board and commissioners, as well as the parents, should be invited to such meetings. A lunch, served by the pupils at these meetings, is often effective in arousing interest. General meetings should be held at places where the largest number of persons may be reached and should be advertised sufficiently far ahead so that parents will plan to attend. Playlets given by the children will always be interesting to parents, particularly to those with children in the cast.

COMMUNITY CONDITIONS WHICH MAY CONTRIBUTE TO MALNUTRITION.

A survey of community conditions should be made to bring out the factors influencing malnutrition, in accordance with the discussion on pages 3–5. Factors of the kind mentioned in the following paragraphs should be particularly considered in rural districts.

The lack of medical and dental service in rural communities is a very important factor in influencing malnutrition. Information regarding names and addresses of county physicians and nurses, and the names of city, county, and State health officers, the location and telephone number of the nearest hospital, and the names, addresses, and telephone numbers of physicians, nurses, and dentists in near-by towns, if collected and distributed to every rural home, should be of benefit in helping to bring country people into contact with those competent to give medical, nursing, or dental care. Traveling clinics have furnished services of inestimable value in certain rural regions. Health motor cars, supported by cooperating counties, also have proved their worth in several States. In one county in Ohio the local dental association made available the equipment for a traveling dental clinic and paid the salary of the dentist who accompanied it. The employment by a county of one or two itinerant dental hygienists should prove valuable.

While most farms have vegetable gardens, there is often a great lack of variety in the vegetables grown and a marked deficiency in the amount of green vegetables. In few instances is a sufficient amount of vegetables grown for use during the producing months; much less often is the supply large enough to permit some to be canned or dried for winter.

Although there is usually at least one dairy cow for each farm, in many instances all of the milk is sent to the creamery, with either no reservation or an insufficient one for the children in the farmer's family. In some localities, particularly in the South, many farmers are without cows and fresh milk is scarce.

Usually the main meal in the rural home is served at noon, when the school children are often absent, and too frequently the school children do not get a sufficient amount of nourishing food in the evening. In some instances rural children get no hot meal whatever during the day, since they have a cold lunch at school while the family's hot meal is being served at noon.

Coffee and tea drinking is very common among rural children, who often lack the very essentials of a proper diet which one would expect to find in the country, such as unskimmed milk, butter, and green vegetables. In too many instances these food essentials are shipped away, little or none being left for the children of the home.

The rural schoolroom is often badly ventilated and efforts to conserve fuel at home mean that many rural children breathe much bad air.

In many instances the water supply for the rural school is distant. and the children take little water during the day. Rural children often have long distances to walk to school and back and are sometimes given heavy chores at home, and these activities increase their energy requirements and induce overfatigue.

The lack of sanitary conveniences in many farm and school houses also has an important bearing on the health of rural children.

CENTERS FOR SERVICE, EQUIPMENT, AND STAFF.

For children under school age, the grange hall, the school or other community center, and the church generally offer convenient places for the conduct of nutrition work. The accessibility of the center should be carefully considered, and wherever possible the schools should be equipped with health rooms, which will make them useful as locations for work with the preschool as well as the school child.

In most rural communities the church or school is used as the center for so many activities that creed differences are not important. Where these differences are sharp, however, lines are drawn which make the use of the church inadvisable.

For the child of school age, the school probably will be the most convenient place. Permission to use the school building during school hours must be obtained from the county superintendent of schools or the rural-school trustees or committee. Rural children often have far to go to reach home, and in almost all instances weighing and measuring must be done during school hours. The approval of the superintendent usually is readily obtained when the matter has been fully explained. It is very essential that the teacher's enthusiastic cooperation be secured, for health education in the school must be left in her hands.

In the beginning the only equipment that can be expected in most rural schools is a set of scales, individual and class weight charts, and a simple hot lunch equipment.

Weighing and measuring may be done by the teacher or some other person, and local physicians are usually entirely willing to give physical examinations to those 10 per cent or more underweight. If physicians are not available, examinations may be given by a nurse. Consultant service of a trained nutrition worker should be available wherever possible for advice and guidance in nutrition problems. Such a person may be employed on part time provided the necessary connections can be made, and if there is in the community a married woman, well trained in home economics, or some local worker such as a home demonstration agent, Red Cross nutrition worker, or itinerant Smith-Hughes home economics teacher, her services may well be utilized.

When the community is not provided with dental services, an itinerant dentist may be secured. In one county in which nutrition work on an intensive scale was done, the dental association supplied the equipment for a traveling clinic and assisted in paying the dentist.

FINANCING THE WORK.

In the rural districts public support for this work will usually come slowly, but when it is well established and the parents' indorsement has been secured, interest spreads rapidly and county commissioners often may be induced to appropriate funds, especially for the hot midday meal at school.

The importance of a nourishing noon meal should be emphasized at rural teachers' institutes, and the character and cost of scales and hot lunch equipment and ways and means of meeting such expenses form fruitful subjects for discussion. In many rural districts county officials will not vote funds until the midday meal at school has been tried out; in such cases entertainments have been given to raise the money.

OBTAINING HOME COOPERATION.

The objects of the work should be carefully explained to the public at some local church or social meeting, and parents should indorse the plan before work is started with their children. Home cooperation is fundamental and home contacts should be made through a resident trained worker, if possible, such as the county nurse or home demonstration agent. If they are not available, some other local person should be trained for the purpose, since a temporary worker in the community usually is considered an intruder. Home visits are essential, for without the personal touch parents have but little information as to what is developing. They have not the means for obtaining information possessed by the urban resident. Mothers and fathers should be urged to come to the class while the children are being weighed and remain after the weighing for special discussion.

Valuable contacts may be made by having one or two especially tactful mothers of children who have gained visit the homes of children who have not gained. Experience of friends and neighbors will often be accepted by the rural woman where the dictum of a trained worker would not be accepted. Sometimes it will be found that the child's nutrition is considered a matter too personal for an outsider to discuss. Reports concerning the progress of children who have gained will help to stimulate parents of undernourished children to bring them into the gaining group.

THE EDUCATIONAL POSSIBILITIES OF THE LUNCH IN THE RURAL SCHOOL.

The fact that the rural child is in school all day, and that the luncheon hour is something of a social occasion, gives rise to an opportunity for discussing nutrition in a natural way. The rural teacher usually knows conditions in the homes of the children more intimately than the urban teacher, and this often makes it possible to do unusually effective educational work during the lunch hour. Home interest usually will be reflected in better lunches brought to the school, and, if its educational possibilities are utilized, the hot midday meal at school will have an important influence on home diet.

Milk may be brought to school individually, by the children in quantity, by children taking turns, or by some children who furnish it regularly for the entire group, the members of which will pay the cost. Whoever supervises the work should see that every precaution is taken to keep the milk cool and sweet and to safeguard its purity and quality by securing it from sources approved by local health authorities. Where milk can not be secured that has been pasteurized or proved pure by expert test, it is always safer to boil it. In localities where the local supply of milk is unsatisfactory, either because of quality or availability, powdered milk may be made to serve almost as well as fresh milk, especially for soup or cocoa.

APPENDIX.

Some Good Food Habits.[1]

At least a pint of clean, pure milk a day—a quart wherever possible. Where a quart is used, it is preferable that not more than one cupful or glassful should be drunk at each meal; the remainder should be used on cereals and in cooked foods, such as creamed vegetables and meats, custards, junket, and blanc mange.[2]

At least two vegetables every day; a green or leafy vegetable two or three times a week.

Bread and butter, or whole grain cereal with unskimmed milk, in some form at every meal.

Fresh fruit every day.

Some eggs, poultry, or meat every day. (Preferably meat should not be used at night.)

No tea or coffee.

No sweets between meals.

Chew food thoroughly. Do not wash it down with liquids.

Eat slowly; sit down at mealtimes.

Some Good Health Habits.[1]

Drink three or four glasses of water every day. (One glass should be taken immediately upon arising.)

Sleep each night the number of hours indicated below.[3] Bedroom windows should be opened wide, and children should be covered warmly in cold weather.

	Hours.
4 and 5 years, at least	12
6 and 7 years	11½
8 and 9 years	11
10 and 11 years	10½
12 and 13 years	10

Play out of doors for at least two hours every day unless it is considered desirable to rest instead. When weather does not permit going out of doors, play indoors with windows open.

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[1] These habits, in general, should be observed by children in varying conditions. Modifications with regard to food, rest, and play, however, should be made, under proper direction, for children of low physical vitality.

[2] If, in the judgment of the physician, a child is not getting enough milk, but has a diet already sufficiently high in calories, milk should be substituted for a portion of the food already given, otherwise overfeeding may result. This is particularly true for children, 2 years old or more, who have a fair amount of meat in the diet. In such cases it is usually inadvisable for milk to be drunk with the midday or main meal.

[3] A rest period may be necessary during the day in addition to the number of hours indicated.

To obtain this much sleep children of the various ages indicated should go to bed at about the times shown below:

4 years, not later than 6.30.
5-7 years, not later than 7.
8-11 years, not later than 8.
12-14 years, not later than 9.

Have a natural bowel movement every day, preferably in the morning right after breakfast.

Wash hands before eating and after going to toilet.

Always carry a handkerchief and be careful to protect other people by holding it over the mouth and the nose and bowing the head when coughing or sneezing.

Brush the teeth at least once a day, especially before going to bed.

Take a full tub or sponge bath at least once a week.

NATIONAL CHILD WELFARE AND HEALTH AGENCIES FROM WHOM SPEAKERS AND EXHIBIT MATERIAL MAY BE OBTAINED.

[No attempt has been made to make these lists all inclusive. Excellent sources have doubtless been omitted.]

Speakers.—The agencies listed below give terms on application. As a rule, speakers from these sources prefer to discuss child health and welfare in general, considering malnutrition as related thereto. Those starred discuss malnutrition more especially.

American Child Health Association, 370 Seventh Avenue, New York, N. Y.

American Red Cross, Washington, D. C., and divisional headquarters at Boston, Atlanta, Chicago, St. Louis, and San Francisco.

American School Hygiene Association, 1101 Fulton Building, Pittsburgh, Pa.

Bureau of Education, United States Department of the Interior, Washington, D. C.

Children's Bureau, United States Department of Labor, Washington, D. C.

*Elizabeth McCormick Memorial Fund, 848 North Dearborn Street, Chicago, Ill.

National Child Labor Committee, 105 East Twenty-second Street, New York, N. Y.

National Tuberculosis Association, 370 Seventh Avenue, New York, N. Y.

*Nutrition Clinics for Delicate Children, 44 Dwight Street, Boston, Mass.

United States Public Health Service, Washington, D. C.

Exhibit material and literature.—Pamphlets, bulletins, charts, posters, lantern slides or films on health and nutritional subjects may be secured from the following agencies which will furnish full information regarding the exact kinds of material available and terms upon which it may be obtained:

American Child Health Association, 370 Seventh Avenue, New York, N. Y. (Reprints from "Mother and Child.") (Exhibits, pamphlets, posters, lantern slides; performances by dramatic characters.)

American Medical Association, 535 North Dearborn Street, Chicago, Ill. (Pamphlets, posters, and lantern slides.)

American Red Cross, Washington, D. C., and divisional headquarters at Atlanta, Boston, Chicago, St. Louis, and San Francisco.

Association for Improving the Condition of the Poor, 105 East Twenty-second Street, New York, N. Y. (Posters and food charts.)

Bureau of Social Education, National Board, Young Women's Christian Association, 600 Lexington Avenue, New York, N. Y (Pamphlets, posters, lantern slides, and motion pictures of interest to girls in their teens.)

Children's Bureau, United States Department of Labor, Washington, D. C. (Bulletins, lantern slides, wall panels, films, and charts.)

Committee on Foods and Nutrition, National Research Council, 1701 Massachusetts Avenue, Washington, D. C.

Elizabeth McCormick Memorial Fund, 848 North Dearborn Street, Chicago, Ill. (Exhibits, posters, lantern slides, films, and pamphlets.)

Joint Committee on Health Problems in Education, Dr. Thomas D. Wood, 525 West One hundred and twentieth Street, New York, N. Y. (Set of 58 health charts, lantern slides, and pamphlet reports.)

Lying-in Hospital, 426 East Fifty-first Street, Chicago, Ill. (Film "Starting the Baby Right.")

National Dairy Council, 910 South Michigan Avenue, Chicago, Ill. (Booklets, posters, lantern slides, and devices.)

National Organization for Public Health Nursing, 370 Seventh Avenue, New York, N. Y. (Lantern slides, films, and pamphlets.)

National Tuberculosis Association, 370 Seventh Avenue, New York, N. Y. (Films, health playlets, Modern Health Crusade material.)

Office of Home Economics, States Relations Service, United States Department of Agriculture, Washington, D. C. (Charts and bulletins on composition of food materials, food selection and meal planning, and children's diet—the last for both white and colored children.)

United States Bureau of Education, Washington, D. C. (Bulletins, classroom weight records.)

United States Public Health Service Washington, D. C. (Literature and samples of forms.)

Many State departments of health or education and also extension departments of State universities can furnish excellent material. For further suggestions, see Nutrition Bibliography compiled by the New York Nutrition Council, issued by Health Service, American Red Cross, New York County Chapter, 598 Madison Avenue, New York, N. Y.

DEFINITION OF MALNUTRITION.

Malnutrition is a term commonly applied to a condition of general physical subnormality in children. Certain characteristic symptoms and pathological signs are usually present which indicate unmistakably that there is a lack of proper development.

Standards for identification.—Probably the most simple test of a child's physical condition is the relation of his weight to his age and height. Other important considerations are muscular development and tone, animation and endurance, and the color and condition of the skin and visible mucous membranes.

Extended clinical studies of individual cases have shown that any child who is habitually 10 per cent or more underweight for his age and height should be classed in the group needing a thorough examination to determine exactly the responsible factors and appropriate treatment required. At the other extreme are those less frequent cases of children who usually show by a condition of obesity that they are not developing normally or are being overfed. Clinical evidence indicates that when a child is 20 per cent above the average weight for his age and height, as a rule, he has reached a point which may be considered abnormal, where he begins to show lessened activity and a general lowering of health, convenience, and comfort; but here also, a thorough examination is most important.

In underdeveloped or undernourished children there will often be found, besides the usual underweight, some or all of the following conditions: Lines under the eyes, anxious expression, pallor, mouth breathing and other indications of nasopharyngeal obstruction; enlargement of the cervical glands, fatigue posture, round shoulders, lateral curvature, flat chest, rigid spine, ptosis, prominent abdomen, pronated or flat feet. By fatigue posture is meant an appearance similar to the stoop which results from muscular weakness in old age. Not all underdeveloped children present these signs, but the majority present some or many of them. Many of these children evince extreme restlessness, nervousness, tenseness, and irritability, while others develop an extreme lassitude.

While the majority of children who need special attention because of undernourishment will be found among the group that is below weight for age and height, there is a small percentage that show a relation between weight for age and height that is equal to the average, but nevertheless fall below par in other respects. These children may be suffering from an inhibition in development, but this can not be determined definitely without taking inheritance[4] and general vitality into account. Under a suitable health régime, with defects eliminated, such children usually manifest a capacity for growth in both weight and height.

There are also occasional individuals who are up to average standards of weight and height but are flabby and inactive and show other signs associated with malnutrition. Underlying such a condition, if it is not due to muscular inactivity, may be some toxic cause, hookworm or a disease due to nutritional deficiency or disturbance. Malnutrition may be a symptom of many serious organic conditions, such as tuberculosis, cardiac disease, syphilis, nephritis, or diabetes, or of grave anemia or previous acute illness, etc. Such cases as these clearly should not be diagnosed as cases of malnutrition, and before children are to be considered as simply suffering from malnutrition these things should be excluded. It is also important, in judging whether a child is making proper progress in physical development, to take careful account of variations in growth which have been observed during certain seasons.

Characteristic signs of improvement.—As children who are underweight and below par physically approach average weight there is usually evidence of a transformation that is both physical and mental. There is a return of color and a glow of health that is unmistakable. Normal reactions appear; those dull and listless become bright and alert, in others restlessness and irritability diminish, the child becoming less "finicky and nervous." Parents often state that the patient "has become a different child."

When physical defects have been corrected and an underdeveloped child has become what may be designated as "free to gain," nature supplies a strong impulse to his development. This is usually evidenced by a rapid advance in weight, the rate of which is gradually reduced as he approaches normal condition.

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[4] It is impossible for a layman to tell whether an excess of weight for height or the reverse is a normal result of heredity and even physicians and trained examiners should only be influenced by such considerations after careful study of all factors.

ADVISORY COMMITTEE ON FOODS AND NUTRITION.

JOSEPH GOLDBERGER, M. D., Chairman.

DEPARTMENTS, BUREAUS, AND ORGANIZATIONS AS REPRESENTED ON THE COMMITTEE.

American Child Hygiene Association	Fritz B. Talbot. M. D., 311 Beacon Street, Boston, Mass.
American Home Economics Association	Ruth Wheeler, Ph. D., Professor of Nutrition, Iowa State University, Iowa City, Iowa.
American Red Cross	Margaret Sawyer, Director of Nutrition Service, Washington, D. C.
American School Hygiene Association	Mary G. McCormick, Supervisor Nutrition of School Children, University of the State of New York, Albany, N. Y.
Child Health Organization of America	Royal S. Haynes, M. D., 140 West Fifty-eighth Street, New York, N. Y.
National Organization for Public Health Nursing	Hazel Corbin, Field Director, Maternity Center Association, New York, N. Y.
National Research Council	E. V. McCollum, Ph. D., Sc. D., Professor of Chemical Hygiene. School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Md.
National Tuberculosis Association	H. R. M. Landis, M. D., 1818 South Rittenhouse Square, Philadelphia, Pa.
United States Bureau of Education	Henrietta W. Calvin, Specialist in Home Economics, Washington, D. C.
United States Children's Bureau	Anna E. Rude, M. D., Director Division of Hygiene, Washington, D. C.
United States Department of Agriculture	C. F. Langworthy, Ph. D., Chief, Office of Home Economics, Washington, D. C., and Florence E. Ward, in Charge Projects and Programs, Eastern States, Office of Extension Work, Washington, D. C.
United States Public Health Service	Joseph Goldberger, M. D., Surgeon, Washington, D .C.

MEMBERS AT LARGE.

Hugh Chaplin, M. D.	141 East Seventy-first Street, New York, N. Y.
Amy L. Daniels, Ph. D.	Professor, Nutrition, Child Welfare Research Station, Iowa City, Iowa.
William R. P. Emerson, M. D.	Director, Nutrition Clinics for Delicate Children, Boston, Mass.
Lucy H. Gillett	Superintendent Nutrition Bureau, Association for Improving the Condition of the Poor, New York, N. Y.
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UNITED STATES PUBLIC HEALTH SERVICE

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MAY, 1923

RAILROAD MALARIA SURVEYS
1922

THE MISSOURI PACIFIC RAILROAD

BY

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Centralia
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T E
Jackson
Holly Springs
Water Valley
Grenada
Winona
Aberdeen Jn.
HELENA
M I S S I S S I P P I
MERIDIAN
Hazlehurst
Brookhaven
McComb
Hattiesburg
Kentwood
Gulfport
NEW ORLEANS

MALARIA SURVEY OF THE MISSOURI PACIFIC RAILROAD, 1922.

PURPOSE AND EXTENT OF SURVEY.

The United States Public Health Service has been deeply interested in the investigation of malaria prevalence, malaria losses, and methods best suited to malaria control along the large railroad systems of the South since a permanent program of malaria investigations was first undertaken by the service in 1914. It has been felt that this interest in the study of malaria as it affects the welfare of the railroads and the stimulation of malaria control by the railroads is justifiable because (*a*) malaria is of more economic importance to the agricultural and industrial development of the South than any other disease; (*b*) the railroads are the arteries of commerce through which practically all commodities must pass to and from the factories and farms on their way to the consumers; and (*c*) because of their common interest in malaria control and close contact at many points with rural populations, the railroads are in a peculiarly favorable position to assist the State and local health authorities in conducting campaigns of education in malaria transmission and demonstrations of the methods employed in malaria control.

At the request of the State health authorities concerned, malaria surveys have been made by the Public Health Service of the St. Louis Southwestern Railway in 1917 by Senior Sanitary Engineer J. A. LePrince and Epidemiologist T. H. D. Griffitts; of the Central of Georgia Railroad in 1919–20 by Asst. Sanitary Engineer A. F. Allen and Asst. Sanitary Engineer H. N. Old; and of the Illinois Central Railroad in 1920–21 by Asst. Sanitary Engineer J. C. Carter. Following these surveys, the St. Louis Southwestern Railway Co. (Cotton Belt Railroad) and the Central of Georgia Railroad immediately undertook to carry out the recommendations made for malaria control and instituted comprehensive programs for malaria control among their employees and upon the railroad property. In addition both railroads are cooperating with the State and local health authorities in carrying on urban malaria control at many points along these railroads. The Illinois Central Railroad also increased its activities in malaria control following the survey and is now cooperating with the State and local health authorities, particularly in southern Illinois and western Mississippi, in the control of malaria in urban communities along its lines.

Upon the request of the State health authorities of Missouri and Arkansas, a malaria survey of the Missouri Pacific Railroad lines south of St. Louis was undertaken by the service late in 1921, Associate Sanitary Engineer A. W. Fuchs being assigned to this detail. The objects of this survey were as follows:

(*a*) To determine as accurately as possible malaria prevalence among railroad employees.

(*b*) To outline the extent of the malaria problem along the road.

(*c*) To make necessary recommendations for practical malaria control.

(*d*) To prepare an estimate of the cost of malaria control.

This survey was completed early in 1922, and it is believed that the report, as given below, will prove interesting and instructive not only to health officials and others who look at malaria control from a viewpoint of health improvement and advancement in public health work, but also to those railroad officials and business men of the South who are beginning to see and feel keenly the close relationship which exists between malaria on one hand and inefficient labor and undeveloped resources on the other.

The survey included:

(1) A study of the records of in-patients at the St. Louis, Little Rock, and Monroe hospitals of the Employees' Hospital Association (the only large hospital omitted was that at Kansas City), also of out-patients at these hospitals and at other points on the system.

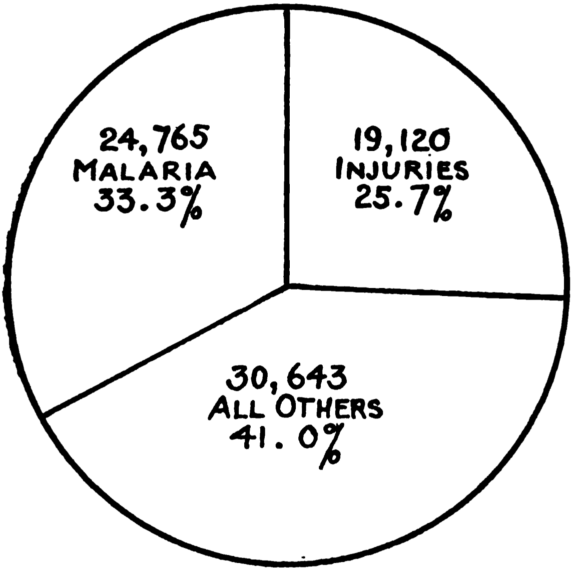

FIG. 2.—Chart showing relative importance of malaria as a cause of admission to hospitals among employees south of St. Louis, 1899-1921.

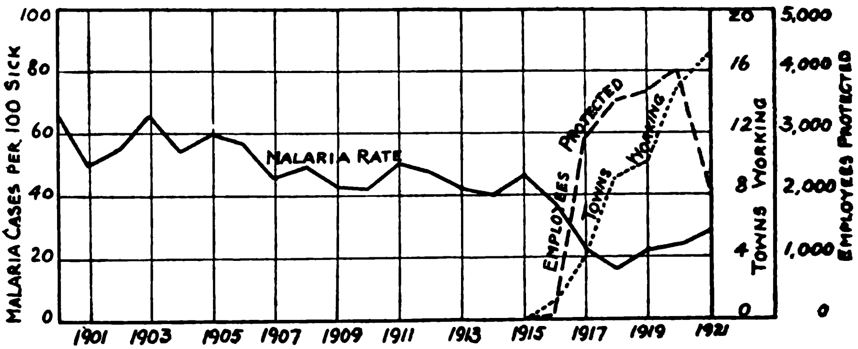

FIG. 3.—Chart showing reduction in hospital malaria rate among employees south of St. Louis after 1915, accompanying inauguration of organized antimalaria work in towns on the Missouri Pacific Railroad.

(2) A malaria census of employees and their families on portions of the Missouri, Arkansas, Memphis, and Louisiana divisions; also statements from foremen, roadmasters, and other railroad men regarding the effect of malaria on the efficiency of labor, labor turnover, and the cost of operation.

TABLE 1.—*Summary of admissions to St. Louis, Little Rock, and Monroe Hospitals, 1899–1921.*

Year.	Lines west of St. Louis.		
	Total.[1]	Malaria.	Malaria cases per 100 total admissions.
1899	768	60	9.0
1900	631	43	6.8
1901	463	30	6.5
1902	1,033	56	5.4
1903	1,109	71	6.4
1904	822	44	5.4
1905	876	52	5.9
1906	1,116	63	5.6
1907	904	39	4.3
1908	763	37	4.8
1909	1,013	43	4.2
1910	1,101	46	4.2
1911	654	32	4.9
1912	523	29	5.5
1913	634	33	5.2
1914	545	14	2.6
1915	687	26	3.8
1916	842	30	3.6
1917	811	20	2.5
1918	750	12	1.6
1919	604	8	1.3
1920	723	7	1.0
1921	534	3	.6
1899–1921	17,906	807	4.5

Year.	Lines south of St. Louis (Iron Mountain).						
	Total.[2]	Sick (including malaria).	Injuries and surgical.	Malaria.	Malaria cases per 100 total admissions.	Malaria cases per 100 sick.[3]	Malaria cases per 100 injured.
1899	2,430	1,820	610	1,627	67.0	89.5	267
1900	2,010	1,510	500	1,016	50.6	67.4	203
1901	2,726	2,021	705	988	36.3	47.9	140
1902	3,275	2,455	820	1,310	40.0	53.4	160
1903	3,520	2,640	880	1,713	48.8	64.8	195
1904	2,590	1,940	650	1,033	39.8	53.3	159
1905	2,750	2,060	690	1,200	43.7	58.3	174
1906	3,540	2,655	885	1,507	42.5	56.7	170
1907	2,840	2,130	710	946	33.3	44.4	133
1908	2,430	1,820	610	885	36.4	48.7	145
1909	3,180	2,385	795	1,002	31.4	42.0	126
1910	3,464	2,545	919	1,055	30.5	41.5	115
1911	4,272	3,207	1,065	1,569	36.7	48.8	147
1912	5,179	3,979	1,200	1,871	36.1	47.0	156
1913	3,447	2,529	918	1,058	30.7	41.8	115
1914	3,292	2,428	864	969	29.4	39.9	112
1915	3,675	2,669	1,006	1,224	33.3	45.8	122
1916	5,078	3,770	1,308	1,429	28.1	37.8	109
1917	3,904	2,827	1,077	667	17.1	23.6	62
1918	3,430	2,529	901	396	[4] 11.5	[4] 15.7	44
1919	2,850	2,101	749	453	15.9	21.6	61
1920	2,763	2,013	750	479	17.3	23.8	64
1921	1,883	1,375	508	368	19.5	26.8	72
1899–1921	74,528	55,408	19,120	24,765	33.3	44.7	130

[1] St. Louis hospital only.

[2] 1899–1909, St. Louis Hospital only; 1910–1912, St. Louis and Little Rock; 1913–1921, St. Louis, Little Rock, and Monroe.

[3] Because of the extreme difficulty of accurately determining the number of employees at work each year, for use in computing the actual hospital malaria rate, the percentage of malaria cases of sick cases is here employed as an approximate index of the relative malaria rates, since the number of sick cases bears a fairly uniform relation to the number of employees, except during widespread epidemics.

[4] Low on account of the influenza epidemic.

(3) The collection of information regarding the number of employees on the entire system, and on the highly malarious divisions, by divisions, occupations, and towns; the number and kind of screenable buildings on these divisions; the important towns in each of these divisions as regards freight revenue.

(4) A detailed inspection of the character and the effectiveness of screening on railroad buildings and bunk cars on the same portions of the system as covered by the malaria census. (See map, fig. 1.) The inspection of screening and the malaria census were made by railroad motor-car on 675 miles of main track (Table 10),

or slightly over one-fourth of the total in these divisions, in company with the respective division superintendents, division engineers, or their representatives.

(5) Surveys of some important shop and division headquarters towns, where many railroad employees are concentrated, with reference to malaria prevalence, drainage, and other antimalaria measures necessary or already undertaken, and the attitude of city officials toward cooperation with the railroad in antimalaria work.

(6) An investigation of the effect of malaria on the output of several large lumber mills that contribute heavily to the railroad's freight revenues, and of the attitude of mill superintendents toward malaria control.

(7) Recommendations, including methods and organization, for the prevention of malaria among employees and in towns contributing largely to the company's revenues, based upon the findings of the survey and upon methods successfully employed by other railroads.

TABLE 2.—*Hospital admissions, by hospitals.*

ST. LOUIS HOSPITAL.

Year.	Total cases.	Sick cases.	Injuries and surgical.	Malaria.	Malaria cases per 100 total admissions.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1899	3,198	2,398	800	1,696	49.9	70.7	212
1900	2,641	1,981	660	1,059	40.1	53.4	160
1901	3,189	2,286	903	1,018	31.9	44.6	113
1902	4,308	3,231	1,077	1,366	31.7	41.3	127
1903	4,629	3,472	1,157	1,784	39.4	51.4	154
1904	3,412	2,559	853	1,077	31.6	42.0	126
1905	3,626	2,719	907	1,252	34.5	46.1	138
1906	4,656	3,492	1,164	1,570	33.7	45.0	135
1907	3,744	2,758	986	985	26.3	35.7	100
1908	3,193	2,395	798	922	28.9	38.4	115
1909	4,193	3,145	1,048	1,045	24.9	33.2	100
1910	3,016	1,789	1,227	618	20.0	34.6	50
1911	2,744	2,058	686	797	29.0	38.7	116
1912	2,583	1,956	627	899	34.8	46.0	143
1913	1,602	1,073	529	241	[1] 15.0	[1] 22.4	46
1914	1,240	868	372	106	8.6	12.2	28
1915	1,480	1,053	427	197	13.3	18.7	46
1916	1,860	1,252	608	246	13.2	19.8	40
1917	1,840	1,213	627	123	6.7	10.1	20
1918	1,705	1,194	511	95	5.6	7.3	19
1919	1,374	962	412	62	4.5	6.4	15
1920	1,643	1,150	493	80	4.9	6.9	16
1921	1,217	852	365	25	2.0	3.0	7
1899–1921	63,093	45,856	17,237	17,263	27.4	37.6	100

LITTLE ROCK HOSPITAL.

Year.	Total cases.	Sick cases.	Injuries and surgical.	Malaria.	Malaria cases per 100 total admissions.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1910	1,549	[2] 1,162	387	483	31.2	41.5	125
1911	2,182	[2] 1,637	545	804	36.9	49.1	147
1912	3,119	[2] 2,340	779	1,001	32.1	42.9	128
1913	2,218	[2] 1,663	555	750	33.9	45.0	135
1914	2,148	[2] 1,612	536	722	33.6	44.7	134
1915	2,231	1,618	613	832	37.3	51.4	136
1916	3,007	[2] 2,256	752	834	27.8	37.0	111
1917	2,022	[2] 1,516	506	379	18.8	25.1	75
1918	1,850	[2] 1,387	463	229	12.4	16.5	50
1919 [3]							
1920	1,355	[2] 1,016	339	263	19.3	25.8	78
1921	705	[2] 529	176	149	21.1	28.1	85
1910–1921	23,988	17,939	6,050	6,692	27.8	37.3	111

[1] From here on the rate is lower because many employees south of St. Louis were sent to the Monroe Hospital which was opened in 1913.

[2] Estimated at 75 per cent of total patients, this being the average percentage in those years in which the actual relation was determined.

[3] No records available.

TABLE 2.—*Hospital admissions, by hospitals*—Concluded.

MONROE HOSPITAL.

Year.	Total cases.	Sick cases.	Injuries and surgical.	Malaria.	Malaria cases per 100 total admissions.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1913 [a]	261	175	86	100	38.3	57.2	116
1914	449	329	120	155	34.5	47.2	129
1915	651	475	176	221	34.0	46.5	125
1916	1,052	800	252	379	36.1	47.4	150
1917	853	616	237	185	21.7	30.1	78
1918	625	473	152	84	13.5	17.8	55
1919	478	359	119	153	32.0	42.5	129
1920	488	353	135	143	29.3	40.5	106
1921	495	368	127	197	39.8	53.3	155
1913–1921	5,352	3,948	1,404	1,617	30.2	40.9	115

[a] Beginning July 28.

MALARIA PREVALENCE AMONG EMPLOYEES.

SIZE OF THE MALARIA PROBLEM.

Malaria has been the most frequent cause of admission to the hospitals of the Employees' Hospital Association during the past 23 years (fig. 2). In this period 25,000 employees were treated for malaria in the hospitals at St. Louis, Little Rock, and Monroe, or an average of over 1,000 a year, constituting one-third of all hospital admissions. For the same period injuries and surgical cases combined totaled only three-fourths of the malaria admissions. Excluding injuries, and considering only natural causes of sickness among hospital patients, malaria looms even more important, contributing 45 per cent of the total. In 1921 over 50 per cent of all medical admissions to the Monroe hospital were for malaria. From 1900 to 1915 there was a fairly uniform but slow decline in the malaria rate, due probably to improved drainage as the country became more completely settled, to the increasing use of screens, and to a wider knowledge of cause and prevention. But the sudden decline between 1916 and 1918 to a rate at the end of this three-year

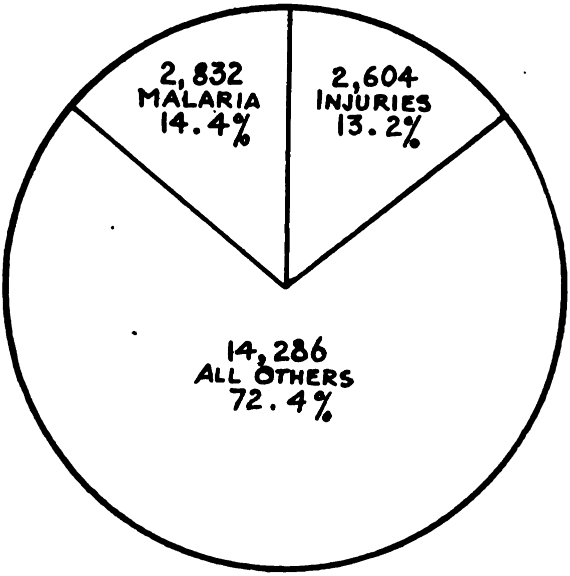

FIG. 4.—Chart showing relative importance of malaria as a cause of out-patient treatment among employees south of St. Louis, 1921.

period only one-third as high as at the beginning was accompanied by an increase in organized malaria control work in towns along the Missouri Pacific Railroad. Although the influenza epidemic of 1918 probably exaggerated the decline for that one year to some extent, in general the malaria rate for the period from 1916 to 1921 corresponds very closely to the number of employees protected (fig. 3).

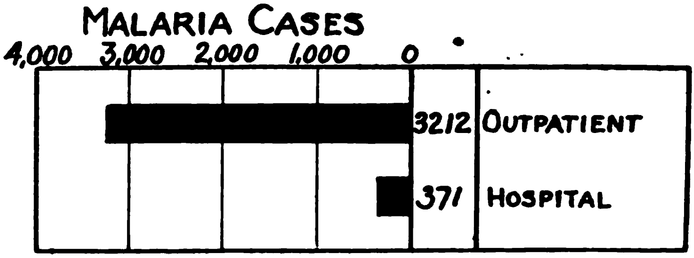

FIG. 5.—Comparison of out-patient treatments for malaria with hospital admissions for the same disease, 1921.

TABLE 3.—*Previous malaria control work in communities on Missouri Pacific Railroad.*

Town.	Population protected (1920 census).	Missouri Pacific employees as of August, 1921.	Control work conducted (indicated by W).						
			Before 1916.	1916	1917	1918	1919	1920	1921
ARKANSAS.									
Arkadelphia	3,300	16							W
Conway	4,600	[1] 25							W
Crossett	2,700	10		W	W	W	W	W	W
Dermott	2,300	54				W	W	W	W
El Dorado	5,500	114						W	W
Eudora	1,200	[1] 20					W	W	
Hamburg	1,500	7			W	W	W	W	W
Helena (part)	[2] 4,500	168							W
Jerome	1,200	[1] 10					W	W	W
Lake Village	1,400	31				W	W	W	W
Little Rock	65,000	461			W	W	W	W	W
Malvern	3,900	17						W	
McGehee	2,400	643					W		W
Monticello	2,400	14				W	W	W	W
North Little Rock	14,000	2,419			W	W	W	W	
Pine Bluff (part)	[2] 1,000	65						W	W
Prescott	2,700	16							W
Russellville	4,500	[1] 50							W
Texarkana	20,000	216						W	W
LOUISIANA.									
Alexandria	17,500	421				W			
Bastrop	1,500	[1] 10						W	
Lake Charles	14,000	105				W			W
Monroe	17,000	604						W	
TOTALS.									
Number of towns			0	1	4	9	10	15	17
Population protected			0	2,700	83,200	120,800	94,100	140,600	139,000
Missouri Pacific employees protected			0	10	2,897	3,526	3,669	4,052	2,005

[1] Estimated.

[2] Estimated population protected, not entire population.

TABLE 4.—*Out-patient cases, Missouri Pacific Railroad.*

(See also out-patient records for other places, Table 14.)

KANSAS CITY.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1921	2,081	1,959	122	[1]5	0.2	0.3	4

ST. LOUIS.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1919	[illegible]	[illegible]	[illegible]	99			
1920	4,580	[illegible]	773	128			
1921	6,315	6,115	[2]900	142			
1919–1921	17,492	15,286	2,197	369	2.1	2.5	15

LITTLE ROCK.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1917	4,445			282			
1918	2,919			394			
1919	2,770			492			
1920	3,086			404			
1921	3,282	2,883	349	318			
1917–1921	17,221	[3]14,551	[4]2,570	1,890	10.7	21.9	128

NORTH LITTLE ROCK.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1915	13,929	11,209	2,720	2,708			
1916	[illegible]	[illegible]	2,402	[illegible]			
1917	[illegible]	[illegible]	[illegible]	[illegible]			
1918	[illegible]	12,570	[illegible]	2,652			
1919[5]							
1920	12,131	[illegible]	[illegible]	[illegible]			
1921	9,714	[illegible]	[illegible]	[illegible]			
1915–1921[6]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.2	134

McGEHEE.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1920	[illegible]	[illegible]	[illegible]	309			
1921	[illegible]	[illegible]	[illegible]	[illegible]			
1920–1921	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67

MONROE.

Year.	Total.	Sick.	Injured.	Malaria.	Malaria cases per 100 total out-patients.	Malaria cases per 100 sick.	Malaria cases per 100 injured.
1919	[illegible]	[illegible]	[illegible]	[illegible]			
1920	[illegible]	[illegible]	[illegible]	[illegible]			
1921	[illegible]	[illegible]	[illegible]	[illegible]			
1919–1921	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

---

[1] On account of this low figure, no further attempt was made [illegible] Kansas City hospital.

[2] Estimated at 15 per cent of [illegible].

[3] Estimated at 85 per cent [illegible].

[4] Estimated at 15 per cent of total.

[5] Records incomplete.

[6] 1919 omitted; records incomplete.

Only the more severe cases of malaria enter the hospital. Every year many more thousands of employees are given out-patient treatment for malaria by local surgeons of the hospital association, located in all towns of any size along the railroad. The chief surgeon's report for 1921 shows only 4,000 hospital patients treated for all causes, against 74,000 out-patient treatments. Less than one-eighth of the employees receiving out-patient treatment for malaria were admitted to the hospital in 1921 (fig. 5). In many places over 50 per cent of the railroad employees were treated for malaria by local surgeons in 1921 (Table 14).

After all, hospital records and those of local surgeons recite only two chapters of the story. The malaria census shows that only 18 per cent of the employees on four southern divisions who reported having had malaria in 1921 entered the hospital (fig. 13); that is, for every employee receiving hospital treatment for malaria there were four or five others who had malaria but did not enter the hospital. It also shows that only 68 per cent of malarial employees on these divisions even visited a doctor. It reveals an astounding rate of infection—32 per cent of the 483 employees interviewed on four southern divisions reported having had malaria in 1921 (fig. 12).

TABLE 5.—*Hospital malaria cases, by divisions, 1919–1921.*

Hospital and year.	Missouri division.	Arkansas division.	Memphis division.	Louisiana division.	Central division.	Other Iron Mountain divisions.	Not Iron Mountain.	Not stated.	Total.
St. Louis:									
1919	23	5	2	5	0	19	8	0	62
1920	22	6	8	13	0	21	7	3	80
1921	4	5	2	4	0	6	3	1	25
Little Rock:									
1919[1]									
1920	6	108	80	53	8	8	0	0	263
1921	13	72	28	22	3	11	0	0	149
Monroe:									
1919	0	1	12	136	0	0	0	4	153
1920	0	1	15	123	0	0	0	4	143
1921	0	1	25	159	0	0	0	12	197
Combined:									
1919[2]	23	6	14	141	0	19	8	4	215
1920	28	115	103	189	8	29	7	7	486
1921	17	78	55	185	3	17	3	13	371
1919–1921	68	199	172	515	11	65	18	24	1,072
Per cent of total:									
1919[2]	11	3	6	65	0	9	4	2	100
1920	6	24	21	39	2	6	1	1	100
1921	5	21	15	49	1	5	1	3	100
1919–1921	6	19	16	48	1	6	2	2	100

[1] Records not available.

[2] St. Louis and Monroe hospitals only.

Over 3,200 malaria cases were treated by local physicians in 16 towns during 1921, when the railroad was operating with a reduced personnel (fig. 5). It is conservatively estimated that under normal conditions at least 6,000 employees have malaria each year, concentrated almost entirely on four southern divisions. There is no doubt that on the southern divisions malaria occurs more frequently than any other disease. On some divisions it affects one-third of the employees.

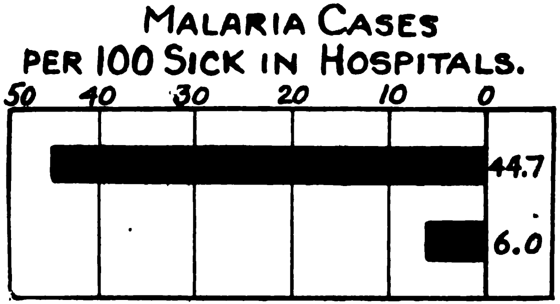

FIG. 6.—Chart showing relative hospital malaria rates on northern and southern portions of the system, 1899–1921.

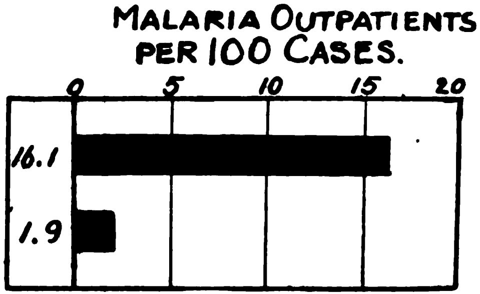

FIG. 7.—Chart showing relative out-patient malaria rates on northern and southern portions of the system, 1921.

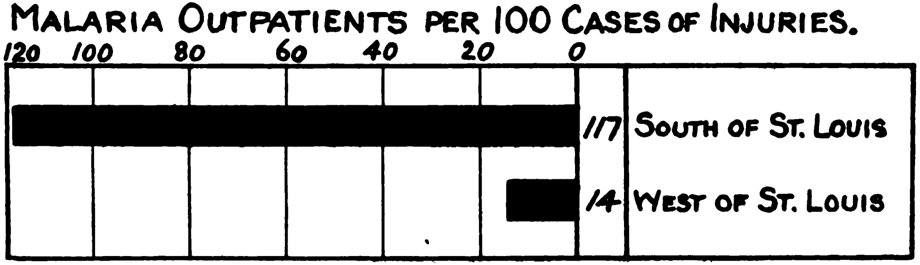

FIG. 8.—Chart showing relative importance of malaria and injuries, out-patient service, 1921.

MALARIA BY DIVISIONS.

The hospital malaria rate from 1899 to 1921 was eight times higher among employees on lines south of St. Louis (formerly the Iron Mountain Railway) than among those west of that point (fig. 6), and a similar condition is indicated for out-patients (fig. 7). South of St. Louis malaria is far more frequent than injuries; west of this place the reverse is true (fig. 8). On the southern portion of the system malaria control deserves greater attention than the safety-first campaign.

The Louisiana, Memphis, Arkansas, and Missouri divisions, with only one-third of the system employees, contributed nine-tenths of the hospital malaria cases in 1920 and 1921. The hospital admission rates for malaria per 1,000 employees are shown for the different parts of the system in Figure 9. It is seen that the Louisiana division has by far the highest rate (72.2 per thousand); the Memphis division is next, with a rate of 38.8; and the Arkansas, Missouri, and Central divisions follow in the order named. For 1920–21 the rate for the entire system was 11.5, while that for lines west of St. Louis was only 0.3 per thousand, and for lines south of St. Louis 22.7.

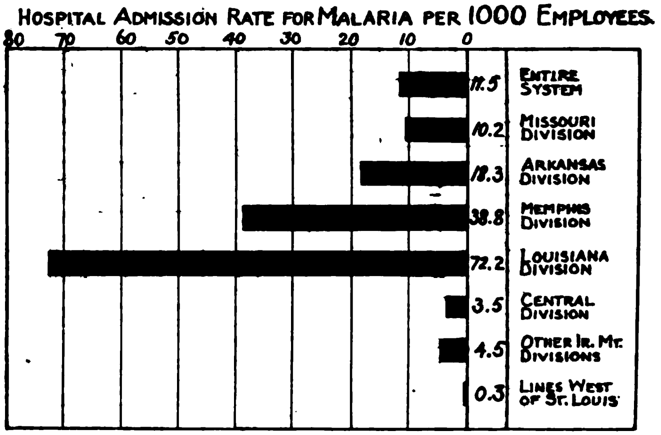

FIG. 9.—Chart showing hospital admission rate for malaria per 1,000 employees, by divisions, 1920–21.

TABLE 6.—*Average number of employees, entire system.*

[Figures represent monthly averages.]

1919	38,451
1920	41,184
1921	33,462
Annual average	37,699

Table 7.—*Average number of employees on southern divisions in operation December 31, 1921.*

[Former Valley division employees apportioned among Arkansas, Memphis, and Louisiana divisions for 1919 and 1920.]

MISSOURI DIVISION.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	286	382	516	254	930	2,368
1920	292	385	522	221	1,048	2,468
1921	251	319	332	168	884	1,954

ARKANSAS DIVISION.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	1,190	667	958	476	2,613	5,904
1920	1,212	716	978	529	2,720	6,155
1921[1]	1,013	567	510	259	2,057	4,406

MEMPHIS DIVISION.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	419	456	726	242	504	2,347
1920	462	561	759	248	520	2,550
1921[1]	273	353	426	164	308	1,524

CENTRAL DIVISION.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	340	294	480	164	255	1,533
1920	383	317	479	253	281	1,713
1921	319	358	444	79	225	1,425

LOUISIANA DIVISION.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	393	325	880	169	614	2,381
1920	416	419	867	282	695	2,679
1921[1]	368	371	635	176	629	2,179

TOTALS.

Year.	Office, stations, and yard.	Train and engine.	Section.	Extra and bridge and building gangs.	Mechanical.	Total.
1919	2,628	2,124	3,560	1,305	4,916	14,533
1920	2,765	2,398	3,605	1,533	5,264	15,565
1921	2,224	1,968	2,347	846	4,103	11,488
1919-1921	7,617	6,490	9,512	3,684	14,283	41,586
Annual average	2,539	2,163	3,171	1,228	4,761	13,862
Per cent of total	18.3	15.6	22.9	8.9	34.3	100

---

[1] May to December, inclusive.

The malaria census at first glance appears to give different results (fig. 12); for example, the Memphis division shows a higher percentage of employees reporting malaria in 1921 than the Louisiana division. This apparent discrepancy is in the main explained by the greater severity of the disease on the Louisiana division, as indicated (figs. 13, 14) by the higher percentage of cases entering the hospitals, the greater proportion of cases visiting the doctor, and the higher rate of lay-offs from work. Table 10 gives the rates of infection on the several branches of each division on which a census was taken.

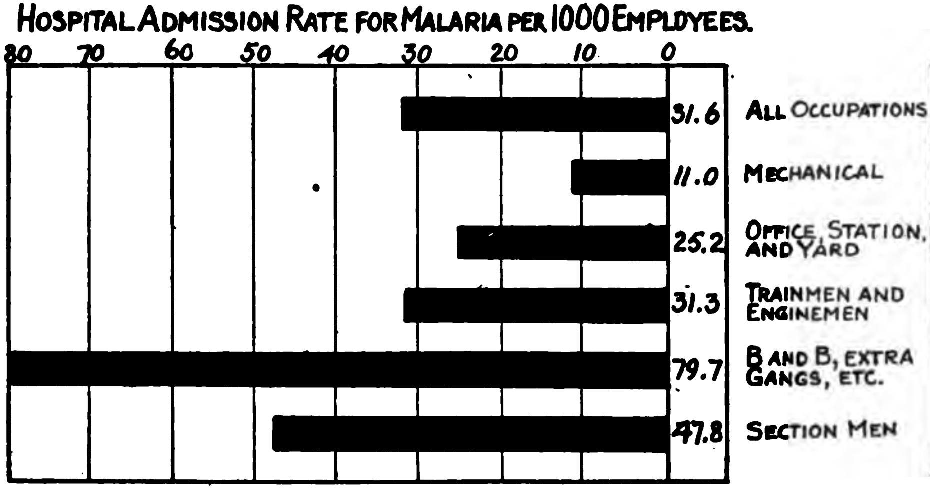

FIG. 10.—Chart showing hospital admission rate for malaria per 1,000 employees, by occupations, 1920-21, among employees on southern divisions.

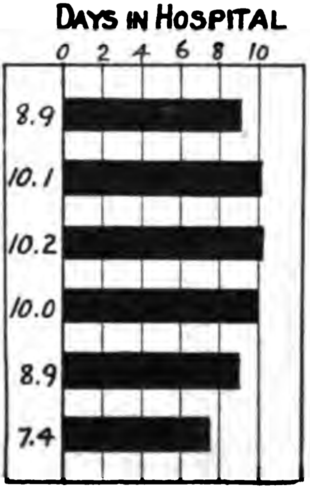

FIG. 11.—Chart showing average time in hospital for malaria by occupations, among employees on southern divisions, 1919-1921.

MALARIA BY OCCUPATIONS.

Of the five groups of occupations into which the employees on the southern divisions were divided, section men sent more malaria cases to the hospitals than any of the others in 1920 and 1921 and shop men the least. The hospital admission rate for malaria per 1,000 employees is shown for the various occupations in Figure 10. It is seen that in 1920 and 1921 bridge and building crews and extra gangs had a rate of 79.7, section men 47.8, train and engine men 31.3, office, station, and yard employees 25.2, shop men 11.0. The hospital malaria rate on the southern divisions for all occupations was 41.6 per thousand.

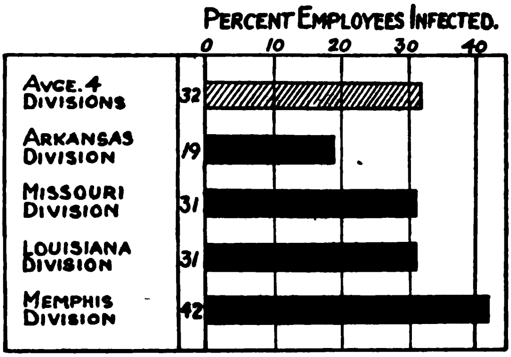

FIG. 12.—Chart showing prevalence of malaria among employees, by divisions, 1921 census.

TABLE 8.—*Hospital malaria cases, by occupations, 1919–1921.*

Hospital and year.	Office, station, and yard	Train and engine.	Section.	Extra gang, bridge and building, etc.	Mechanical.	Not stated.	Total.
St. Louis:							
1919	17	18	10	7	10	0	62
1920	24	18	16	5	17	0	60
1921	6	3	6	1	9	0	25
Little Rock:							
1919[1]	.....	.....	.....	.....	.....	.....	.....
1920	39	41	90	60	33	0	263
1921	25	35	25	34	30	0	149
Monroe:							
1919	18	15	54	44	18	4	153
1920	18	14	53	49	5	4	143
1921	14	26	94	41	9	13	197
Combined:							
1919[2]	35	33	64	51	28	4	215
1920	81	73	159	114	55	4	486
1921	45	64	125	76	48	13	371
1919–1921	161	170	348	241	131	21	1,072
Per cent of total, 1919–1921	15.0	15.9	32.4	22.5	12.2	2.0	100.0

[1] Records not available.

[2] St. Louis and Monroe hospitals only.

TABLE 9.—*Days in hospital for malaria, by occupations of employees.*

Hospital and year.	Office, station, and yard.			Train and engine.			Section.		
	Cases.	Total days.	Days per case.	Cases.	Total days.	Days per case.	Cases.	Total days.	Days per case
St. Louis:									
1919	17	194	....	18	233	....	10	129	....
1920	24	361	....	18	212	....	16	133	....
1921	6	38	....	3	57	....	6	43	....
Little Rock:									
1919[1]	....	....	....	....	....	....	....	....	....
1920	39	353	....	41	387	....	90	621	....
1921	25	264	....	35	443	....	25	210	....
Monroe:									
1919	18	165	....	13	74	....	52	331	....
1920	16	129	....	14	88	....	51	358	....
1921	11	70	....	25	169	....	92	691	....
Combined:									
1919[2]	35	359	10.3	31	307	9.9	62	460	7.4
1920	79	853	10.8	73	687	9.4	157	1,112	7.1
1921	42	372	8.9	63	669	10.6	123	944	7.7
Total, 1919-1921	156	1,584	10.2	167	1,663	10.0	342	2,516	7.4

Hospital and year.	Extra gangs, bridge and building, etc.			Mechanical.			Total.		
	Cases.	Total days.	Days per case.	Cases.	Total days.	Days per case.	Cases.	Total days.	Days per case.
St. Louis:									
1919	7	154	....	10	74	....	....	....	....
1920	5	56	....	17	207	....	....	....	....
1921	1	3	....	9	147	....	....	....	....
Little Rock:									
1919[1]	....	....	....	....	....	....	....	....	....
1920	59	410	....	33	429	....	....	....	....
1921	33	399	....	30	263	....	....	....	....
Monroe:									
1919	43	374	....	16	129	....	....	....	....
1920	48	413	....	5	29	....	....	....	....
1921	39	286	....	9	30	....	....	....	....
Combined:									
1919[2]	50	528	10.5	26	203	7.8	204	1,857	9.1
1920	112	879	7.9	55	665	12.1	476	4,196	8.8
1921	73	688	9.4	48	440	9.2	349	3,113	8.9
Total, 1919-1921	235	2,095	8.9	129	1,308	10.1	1,029	9,166	8.9

[1] Records not available.

[2] For St. Louis and Monroe hospitals only.

This is what would naturally be expected from a comparison of the liability to exposure to malaria infection in the various occupations. Bridge and building crews and extra gangs are "floating forces" living in bunk cars often located near a river swamp or a stream producing Anopheles mosquitoes in great numbers. The great bulk of the section men live in rural or semirural communities where drainage is not as complete as in the larger towns where the shopmen and many of the office, station, and yard employees have their homes. Trainmen and enginemen occupy an intermediate position in that, though they are "semifloating," they generally live in large towns at both ends of their "run."

The malaria census shows no marked difference among the groups as regards the percentage of employees reporting malaria in 1921. This is due mainly to the comparatively small number of employees, interviewed in all occupational groups except section men.

MALARIA IN EMPLOYEES' FAMILIES.

A malaria census of employees' families, practically all of them families of section foremen, including 49 families containing 260 individuals, was taken along with the census of employees. Seventy per cent of all families interviewed reported at least one case of malaria in 1921; and 34 per cent of all persons in all families reported having had the disease that year (fig. 15). The latter figure corresponds very closely with the rate of infection found in the census of employees. The malaria rate is highest both by families and by members of families on the Louisiana division, with the Memphis, Missouri, and Arkansas divisions following in the order named.

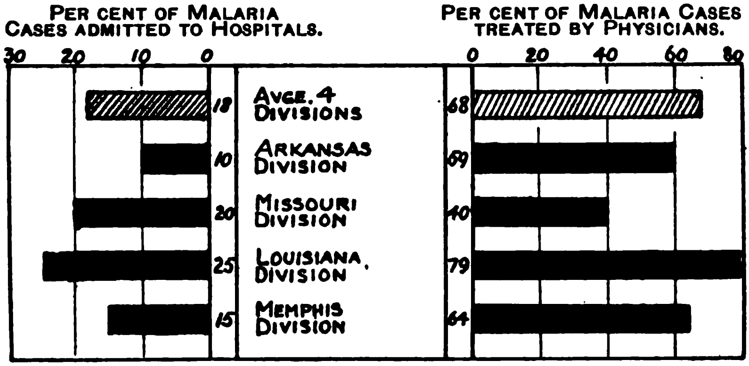

FIG. 13.—Chart showing severity of malaria among employees, by divisions, 1921 census.

TABLE 10.—*Summary of malaria census of Missouri Pacific Railroad employees, by divisions, 1921.*

Branch.	Distance (miles).	Number of employees interviewed.	Malaria cases.		To hospital.			To doctor.			Laid off.			Time lost.		
			Number.	Per cent infected.	Number of cases reporting.	Number to hospital.	Per cent.	Number of cases reporting.	Number to doctor.	Per cent.	Number of cases reporting.	Number laid off.	Per cent.	Number of cases reporting.	Total days lost.	Days per case.
ARKANSAS DIVISION.																
Little Rock to Pine Bluff	43	26	4	15	4	0	....	4	2	50	4	1	25	1	14	14
Pine Bluff to Benton	46	26	3	12	3	0	....	3	2	67	3	1	33	1	2	2
Benton to Hope	89	54	13	24	13	2	15	10	6	60	13	4	31	3	42	14
Combined	178	106	20	19	20	2	10	17	10	59	20	6	30	5	58	13
MISSOURI DIVISION.																
Poplar Bluff to Hoxie	61	15	5	33	3	1	33	3	2	67	3	1	33	0	0	....
Poplar Bluff to Charleston	59	30	9	30	7	1	14	7	2	28	7	4	57	0	0	....
Combined	120	45	14	31	10	2	20	10	4	40	10	5	50	0	0	....
LOUISIANA DIVISION.																
McGehee to Monroe	93	87	23	24	13	7	54	13	11	85	13	12	92	8	145	18
Collinston to Vidalia	106	102	35	36	35	5	14	35	27	77	35	28	80	28	299	11
Combined	199	189	58	31	48	12	25	48	38	79	48	40	83	36	444	12
MEMPHIS DIVISION.																
Wynne to Helena	48	62	13	21	13	2	15	13	7	54	13	6	46	6	27	5
Marianna to Memphis	51	47	39	83	39	6	15	15	11	73	6	4	67	3	19	6
Memphis to New Augusta	79	34	9	26	9	1	11	0	0	....	9	3	33	3	25	8
Combined	178	143	61	42	61	9	15	28	18	64	28	13	46	12	71	6
Summary	675	483	153	32	139	25	18	103	70	68	106	64	60	53	578	11

EFFECT OF MALARIA ON OPERATING COSTS AND RAILROAD REVENUES.

COST OF MALARIA TREATMENT BY HOSPITAL ASSOCIATION.

During 1920, when the railroad operated with a personnel below normal, about 500 malaria cases were treated in the hospitals, with an average of 9 hospital days per case (fig. 11). At an average cost of $2.71 per hospital day, for the St. Louis, Little Rock and Monroe hospitals in 1920, this amounted to over $12,000. In addition, over 4,000 malaria cases received out-patient treatment during the same year at an average cost of $3.27 per patient, amounting to over $13,000. This annual expenditure of $25,000 for *curing* employees, invested in an effective malaria *prevention* organization, would not only greatly reduce the malaria rate, but would effect a proportional saving in the far heavier losses produced by malaria on operating costs and on railroad revenues.

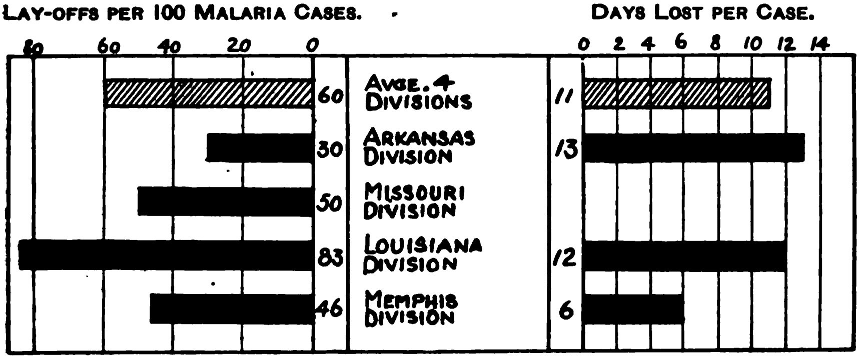

FIG. 14.—Chart showing time lost from work by employees on account of malaria, by divisions, 1921 census.

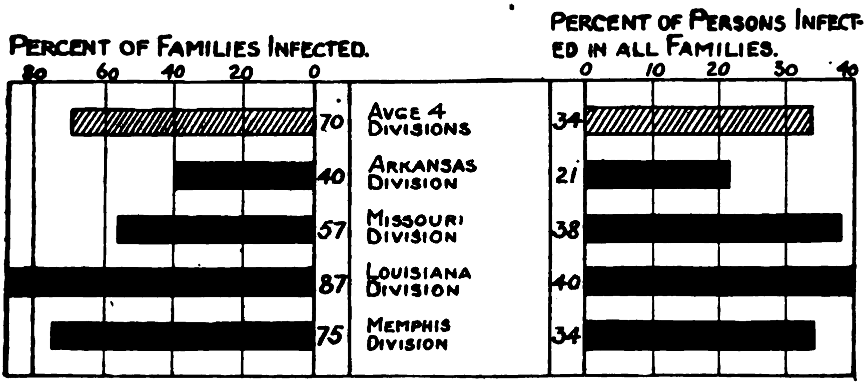

FIG. 15.—Chart showing prevalence of malaria in employees' families, by divisions, 1921 census.

TABLE 11.—*Malaria census of Missouri Pacific Railroad employees' families, by divisions, 1921.*

Branch.	Number of families interviewed.	Number of families infected.	Per cent of families infected.	Number of persons in all families.	Number of infected persons.	Per cent of persons infected.
ARKANSAS DIVISION.						
Little Rock to Pine Bluff	4	2	50	20	5	25
Pine Bluff to Benton	2	0	0	10	0	....
Benton to Hope	4	2	50	14	4	28
Combined	10	4	40	44	9	21
MISSOURI DIVISION.						
Poplar Bluff to Hoxie	4	2	50	26	7	27
Poplar Bluff to Charleston	3	2	67	21	11	52
Combined	7	4	57	47	18	38
LOUISIANA DIVISION.						
McGehee to Monroe	8	7	87	42	17	41
Collinston to Vidalia	8	7	87	38	15	39
Combined	16	14	87	80	32	40
MEMPHIS DIVISION.						
Wynne to Helena	5	4	80	30	9	30
Marianna to Memphis	4	3	75	17	9	52
Memphis to New Augusta	7	5	71	42	12	28
Combined	16	12	75	89	30	34
Summary	49	34	70	260	89	34

MALARIA AND RAILROAD OPERATING COSTS.

Malaria is a disease of primary economic importance. In the acute stage it entails suffering and prevents the patient's working. When the disease becomes chronic, as frequently happens, the employee affected is able to be on the job most of the time, but can work with only a fraction of his normal energy and efficiency, while receiving a full day's pay. Multiplied by several thousand cases, this constitutes an enormous annual charge against the cost of operation. In the acute stage of the disease many employees lay off from work for considerable periods (fig. 14), producing a shortage of labor during busy seasons and slowing down rush jobs. Even when labor is plentiful, new men are inexperienced with their new jobs, and the high labor turnover is costly to the railroad wherever inexperience spells a slacking off of safety precautions, or the unskilled handling of expensive equipment. It is difficult to estimate the increased cost of operation from these causes, but the amount surely is a large one. That those who handle labor on the malarious portions of the railroad realize the handicap is evident from the following statements of section, extra gang, shop, and roundhouse foremen:

General shop foreman, McGehee: Many men come to work with malaria, expecting to take it easy if a chill should come on. They don't want to lose their pay. Many stay on the job even with a chill, and in case a special rush job must be gotten out they will work feebly until it is completed. Subforemen report men laying down on the job on account of the fever, and little work can be got out of such men. The cost of operation is increased by reduced efficiency. When an important job must be rushed through, it has happened that delays are encountered on account of many of the men being sick with malaria. It would pay the railroad well to get rid of malaria.

General roundhouse foreman, Hoxie: In the summer and fall men can't do a good day's work; not laziness at all; men want to give full value, but just can't put out more than two-thirds of a day's work for a full day's pay. Men who are not very sick will try to work, but at great cost to the railroad. Acquainted with antimalaria work done at Camp Pike during the war, and enthusiastic over results obtained. Control work would easily pay the railroad.

Trainmaster, Missouri division: Men working with malaria are only 65 per cent efficient.

Car repair foreman, Ferriday shops: Last year 6 out of the 10 men in the gang laid off on account of malaria. All took sick in late August, within a short time of each other, leaving the job shorthanded for a while. The slacking off in the activity of the men some time previous to their laying off was also noticeable.

Chief supply clerk, Louisiana division: Keeping supply clerks in such places as Ferriday has been difficult on account of "the low country being unhealthy."

Section foreman, Marianna: Men can't work hard with malaria, especially in hot weather; they are forced to ease up, and they lay off every once in a while.

Section foreman, Hughes: Malaria slows up men so that they can't be worked hard. It would pay the company to put on an antimalaria campaign.

Section foreman, Chatfield: Can't get but little work out of men who have malaria. Just when they were most needed last year (in July) they had to go to the hospital.

Foreman, extra gang No. 3, Memphis division: Last summer all the men were sick and taking drugs. Extra men had to be kept on the pay roll to take the place of those sick. This could be done last year because labor was plentiful, but in normal times it couldn't, and it would have delayed the work. Men can't work much during the malaria season.

Discontented employees, worried over the loss of their pay and sickness in their families, can not possess that morale and loyalty so highly important to any organization. Such men will more likely respond to the appeal of the labor agitator. When an employee is forced to lay off several weeks each summer with loss of pay on account of malaria, and in addition has to meet the doctor's and the druggist's bills for treating the family, and sees his children's education handicapped by enforced absence from school, how can he help being discontented? In his case "chills and fever" is equivalent to a cut in pay. (See Fig. 15.)

The pay of salaried employees and those paid by the month is not generally deducted for absence on account of illness. Railway transportation of malarial employees to and from the hospital is without cost to the employees. These are tangible charges against the cost of operation.

MALARIA AND RAILROAD REVENUES.

A territory that has the reputation of a high malaria prevalence is unattractive to prospective agricultural settlers and industries seeking new fields. Such a territory suffers an arrested agricultural and industrial development, and the railroad is a cosufferer. Passenger and freight traffic is a mere skeleton of what it should or could be. That the railroad recognizes these conditions is witnessed by the existence of an industrial commissioner and a director of agricultural development. Does it discern the remedy?

Not only is new settlement discouraged, but farmers and manufacturers already on the ground produce and ship less than they might. On the farm malaria is most prevalent when crops demand greatest attention in cultivating and harvesting. In the mill production suffers from inefficient labor, and at times it is forced to operate at reduced capacity owing to scarcity of labor. Mill superintendents feel the millstone around their necks, and those who have controlled malaria are congratulating themselves, while many who have not are seeking advice and assistance toward that end. The railroad is thereby offered an unusual opportunity for leadership. A few of the letters received from mill men are included in Appendix I and will prove interesting reading. The Crossett Lumber Co. of Crossett, Ark., increased its production 33 per cent by malaria eradication;[1] and the San Augustine Lumber Co. of Keltys, Tex., shipped 20 per cent more lumber the year following control work than ever before, resulting in $30,000 increased freight revenue to the Cotton Belt Railway.[2] The superintendent of the Jerome Lumber Co. at Jerome, Ark., estimates a 10 per cent improvement in his labor efficiency and a more permanent organization as a result of malaria control.

RECOMMENDATIONS FOR A MALARIA CONTROL PROGRAM.

GENERAL CONSIDERATIONS.

The ultimate aim of a railroad malaria control program should be to eliminate malaria wherever it is serious enough to become a charge against operating expenses or to result in loss of revenue. A complete program need not, in fact, could not, be undertaken at the beginning, but the several parts should be adopted in the order of the benefits to be expected per dollar expended. It should include:

(1) Protection of employees against malaria infection by such methods as are most applicable to their mode of living: Effective screening of bunk cars, section houses, and offices; swatting such mosquitoes as gain entrance into bunk cars and section houses; the administration of quinine in prophylactic doses to "floating" gangs, which are most liable to infection, and, possibly, to some section men; the inauguration of antimosquito measures, such as drainage and oiling, in cooperation with municipalities where considerable numbers of railroad employees and their families are concentrated; systematic education of employees in the importance of malaria control by means of personal talks, posters, and exhibits, in order to convert their hostility or passive acquiescence into active cooperation in this program.

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[1] From "Malaria Control Demonstrations," by Sparks, Derivaux, and Taylor; Reprint No. 478, Public Health Reports, July 12, 1918.

[2] From "The Relation of the Railroads in the South to the Problem of Malaria and Its Control," by R. C. Derivaux; Reprint No. 480, Public Health Reports, August 2, 1918.

TABLE 12.—*Condition of screens on Missouri Pacific Railroad property, February–April, 1922.*

Branch and class of building.	Number inspected.	Number unscreened.	Number screened.		Mesh.		Reported mosquitoes gain entrance.	
			Effectively.	Not effectively.	16	Under 16.	Yes.	No.
MEMPHIS DIVISION.								
Wynne to Helena:								
Section houses	7	0	0	7	4	3	5	....
Bunk houses	1	0	0	1	1	0	....	....
Ticket offices	6	0	0	6	3	3	5	....
Freight and baggage offices	4	1	1	2	2	1	1	....
Bunk cars	10	0	2	8	9	1	2	2
Marianna to Memphis:								
Ticket offices	2	0	0	2	1	1	2	0
Section houses	3	0	0	3	2	1	3	0
Memphis to New Augusta:								
Ticket offices	4	1	0	3	1	....	3	....
Section houses	7	0	1	6	5	2	5	1
Bunk cars	3	0	0	3	3	0	2	....
Bunk houses	3	0	1	2	3	0	....	1
Division office	1	0	0	1	0	1	0	1
LOUISIANA DIVISION.								
McGehee to Monroe:								
Store room office	1	0	0	1	1	0	1	0
Bunk cars	2	0	0	2	2	0	....	....
Section houses	7	0	0	7	5	2	6	....
Ticket office	1	0	0	1	1	0	1	0
Collinston to Vidalia, section house	1	0	0	1	0	1	1	0
MISSOURI DIVISION.								
Poplar Bluff to Hoxie:								
Bunk cars	3	0	0	3	0	3	3	0
Ticket offices	4	0	0	4	0	4	4	0
Section houses	5	0	0	5	0	5	3	....
Poplar Bluff to Charleston:								
Section house	1	0	0	1	0	1	....	....
Ticket offices	2	0	0	2	0	2	1	1
Bunk cars	2	0	0	2	0	2	....	....
ARKANSAS DIVISION.								
Little Rock to Pine Bluff:								
Bunk house	2	0	0	2	2	0	1	....
Section houses	3	0	0	3	3	0	2	....
Pine Bluff to Benton, section houses	2	0	0	2	0	2	1	....
Benton to Hope:								
Bunk cars	1	0	0	1	1	0	1	0
Section houses	4	0	0	4	4	0	4	0
TOTALS.								
Section houses	40	0	1	39	23	17	30	1
Bunk houses	6	0	1	5	6	0	1	1
Bunk cars	21	0	2	19	15	6	8	2
Ticket offices	19	1	0	18	6	9	15	1
Freight, baggage, and division offices	6	1	1	4	3	2	2	1
	92	2	5	85	43	34	56	6

TABLE 13.—*Screenable buildings, by divisions, 1922.*

Class of building.	Missouri Division.	Arkansas Division.	Memphis Division.	Louisiana Division.	Total.
Stations:					
(*a*) Passenger			4	5	9
(*b*) Freight			8		[illegible]
(*c*) Combined	70	90	88	112	[illegible]
Bunk cars	42	24	104	82	[illegible]
Section houses	37	65	69	85	[illegible]
Cabooses	38			47	[illegible]
Miscellaneous		62			[illegible]
Total	187	241	273	331	[illegible]

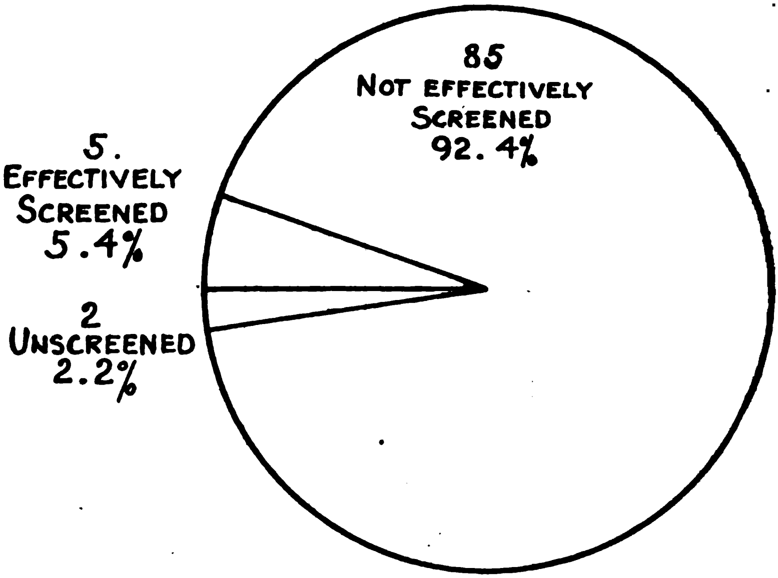

FIG. 16.—Chart showing condition of screening in 92 places investigated.

(2) Cooperation with the several State health officers in pointing out to cities, mill towns, and farming communities the burden they are carrying in the form of limited production from inefficient labor; and the inauguration of cooperative malaria control campaigns [illegible] lighten this burden for their own advantage as well as the railroad's. The financial well-being of the railroad is dependent on that of its territory.

SCREENING AND SWATTING.

The first practical line of defense against malaria in the case of the two classes of employees showing the highest rate of infection, i. e., "floating" gangs (bridge and building, extra, and fence) and section men, is proper screening. The railroad spends many thousand dollars annually for screening bunk cars, section houses, cabooses, offices; yet inspection shows only 5 per cent of them effectively screened (fig. 16). The expenditure is practically wasted because repairs and replacements of screens are made without proper supervision by many different individuals who, though careful in their

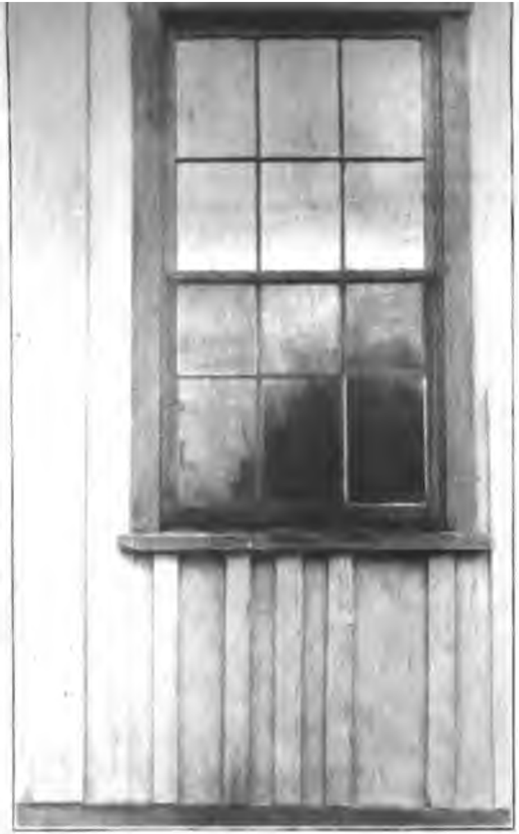

FIG. 17 -A COMMON TYPE OF WINDOW SCREEN ON SECTION HOUSES ONLY LOWER HALF OF WINDOW IS SCREENED WITHOUT A FRAME, THE WIRE BEING TACKED ON.

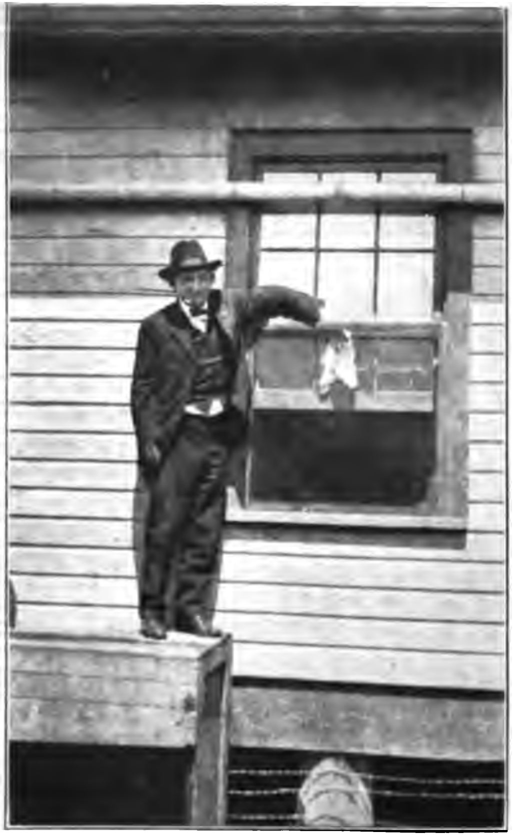

FIG. 18. ANOTHER COMMON TYPE OF WINDOW SCREEN. HALF FRAME DOES NOT FIT AGAINST BOTTOM SASH OF UPPER WINDOW.

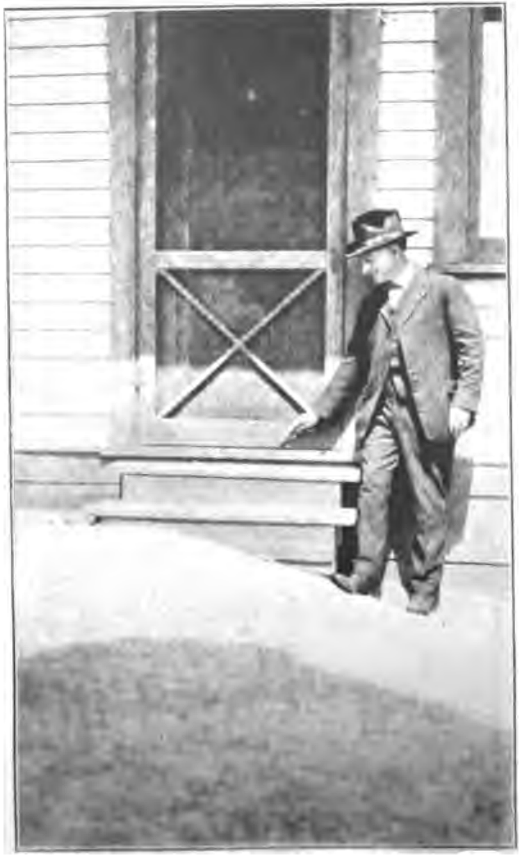

FIG. 19. A WORN DOORSILL THAT RENDERS THE SCREEN INEFFECTIVE.

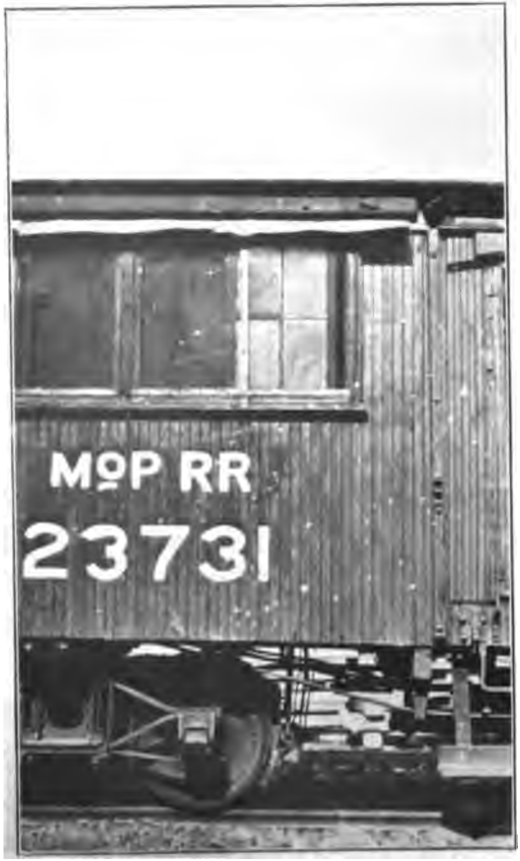

FIG. 20. TYPICAL WINDOW SCREEN FRAME ON BUNK CAR. THE WINDOW SLIDES HORIZONTALLY IN THE FRAME. THE WIRE IS

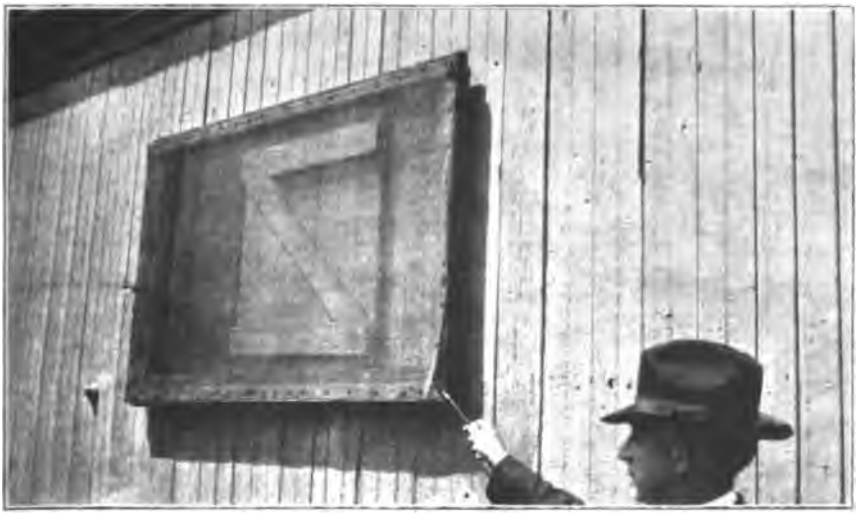

FIG. 21.—WINDOW SCREEN ON A BUNK CAR. THE WIRE IS TACKED ON AND TACKS FALL OUT OR RUST A HOLE IN THE WIRE. STRIPS OF MOLDING NAILED OVER THE EDGES WOULD REMEDY THIS CONDITION.

work, are ignorant of the minute details that must be complied with for mosquito-proof results (figs. 17–21). In its instinctive search for a blood meal the Anopheles mosquito will find the small apertures that are often overlooked. The use of faulty screens affords a false sense of security. A list of faults in screening and specifications recommended for proper screening on malarious divisions of the railroad are included in Appendices II, III, and IV. A competent company carpenter on each of the malarious divisions should be educated in proper screening methods, and should be held responsible for all the screening work on his division. He should be authorized to make trips at regular intervals during the mosquito season to inspect both their construction and maintenance. The importance of proper use, instead of abuse, of screens should be impressed on employees by division officers, and each foreman should be held responsible for the condition and proper use of his screens. Possibly a system of competitive scoring of screen effectiveness, with prizes for the highest scores, would arouse the interest of employees. It is thus possible, without any material increase in cost, to have screens that will keep out mosquitos instead of serving as mosquito traps.

Some Anopheles mosquitoes will gain entrance into houses, and particularly into bunk cars, even with perfect screening, when doors are opened in the evening. Cars should be "spotted," whenever possible, in a mosquito-free locality. Having found a way in, mosquitoes will attack the occupants, but will remain on the walls and screens to digest their meal until morning, when they will attempt to leave. They will find escape more difficult, their appetites satisfied, than gaining entrance, and some will remain to bite again. They can easily be found and swatted while at rest early in the morning, and by this simple method many infected mosquitoes can be destroyed. Systematic swatting in outfit cars by employees should be encouraged (or negro boys hired for this work). In section houses the swatting may be done by employees and their families.

QUININE ADMINISTRATION.

Although screening and swatting provide considerable protection to "floating" gangs and section men, a certain number of these employees are bound to be bitten and infected. Many section men do not live in company houses and are seldom protected by screens. Quinine taken in prophylactic doses, 5 to 7 grains daily, or 16 grains approximately every eighth and ninth day,[3] during the malaria season, will prevent the development of the malarial parasite in the blood in many instances. The company should issue quinine in capsules monthly to foremen of bridge and building, extra, fence, and section gangs for dispensing to their men. The cost would be nominal—about $1.25 per season per employee. Each foreman must be held responsible for the proper distribution and use of the capsules, and must see to it that the men take the quinine instead of throwing it away. The foremen should be required to report monthly the amount taken by each man, with dates. This feature of the program, even more than the others, can not be successful until the foremen and the men have been educated to the value of preventive measures.

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[3] Both dosages have been used successfully. See "Prophylaxis of Malaria," by Senior Surg. (now Assistant Surgeon General) H. R. Carter, United States Public Health Service; reprint No. 454, Public Health Reports, March 27, 1914.

Frequently malaria cases leave the hospital, or discontinue treatment prescribed by local surgeons, in a few days, under the impression that the absence of chills and fever signifies a complete cure. A thorough cure, however, requires complete sterilization and is often obtained only by protracted treatment with quinine. Inadequately treated malaria cases are prone to relapse. Company surgeons can help to reduce such relapses by insisting on prolonged treatment, not necessarily in the hospital; and winter and early spring relapses should be diligently followed up and completely sterilized, as such cases are reservoirs from which mosquitoes carry infection to others. The standard quinine treatment for malaria adopted by the National Malaria Committee and approved by the United States Public Health Service is given in Appendix V.

ANTIMOSQUITO CAMPAIGNS IN RAILROAD TOWNS.

Screening, swatting, and quinine prophylaxis protect the employee against the bite of the mosquito and the development of infection. Antimosquito measures prevent the development of the mosquito itself and are therefore more effective in preventing malaria. The cost of such measures varies with the area protected, hence they are economical in towns, but in rural sections the per capita cost is often prohibitive. Antimosquito work is based on the female mosquito's habit of laying her eggs on the surface of stagnant or slowly moving water, and even on the grass protected edges of rapid streams. The eggs soon hatch into larvæ, or wiggletails; these turn into pupæ, or tumblers, and from the latter finally emerges the adult insect which leaves the water and flies off in search of its first meal. The entire cycle from egg to adult occurs in from 8 to 10 days in hot weather, longer at low temperatures. Drainage and filling eliminate the breeding places. When these are impracticable, oiling destroys the aquatic forms by poisoning and suffocation, or top minnows may be introduced to feed on the larvæ and pupæ; in either case aquatic vegetation must be removed as it affords protection to the "wiggletails." Of the many species of mosquitoes found in this territory only three, the Anophelines, are capable of transmitting the malarial organism from the blood of an infected person to that of a healthy one. Mosquito control as a health measure should be limited to these species; but frequently the public is willing to pay for the elimination of the pestiferous varieties for the sake of comfort.

By the creation of undrained borrow pits, the construction of culverts at so high an elevation as to partially impound water above them and the maintenance of poorly drained ditches, the railroad has added materially to the prevalence of malaria.[4] In future construction these errors should be avoided so far as possible.

Some antimosquito work is advisable around section houses and stations. The section foreman can drain, fill, and oil in the immediate vicinity of the house. At stations fire barrels should be oiled lightly at weekly intervals, water tanks made tight to prevent the formation of pools by leakage, ditches kept clean, and borrow pits drained or filled.

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[4] See also "Railroad Malaria Problems," by H. W. Van Hovenberg, in Public Health Bulletin No. 104.

Antimosquito measures are usually the best protection for employees concentrated in towns, as at shop and division points. Both the municipality and the railroad are interested and should cooperate. In shop towns many of the employees are usually concentrated in the immediate vicinity of the shops and the remainder are scattered throughout the town. An equitable basis of cooperation would be the assumption by the railroad of the work in the shop area and on the right-of-way through town. Where the town will not cooperate the railroad can protect many of its employees by instituting antimosquito measures in the shop area only. The railroad will more readily obtain municipal cooperation by making a malaria survey of the town, outlining proper methods, offering supervisory assistance, and supplying mosquito oil at cost. (In this way it can also be assured of effective control.) The most important towns on the Missouri Pacific Railroad, from the point of view of the number of employees and the malaria prevalence among them, are North Little Rock, Little Rock, McGehee, Monroe, Texarkana, Hoxie, Alexandria, Gurdon, Poplar Bluff, Lexa, Helena, Paragould, Ferriday, Lake Charles, Wynne, and DeSoto (Table 14). Some of these, including North Little Rock, Little Rock, Texarkana, Lake Charles, and possibly others, are continuing antimalaria measures begun in previous years (Table 3); these should be given some cooperation with a view to improving the effectiveness of the work.

Table 14.—*Malaria rates among out-patient employees at most important towns, 1921.*

Town.	Total employees, August, 1921.	Resident employees (office, shop, and yard) August, 1921.	Number treated.	Injured.	Sick, including malaria.	Malaria.	Malaria cases.	
							Per 100 total employees.	Per 100 sick cases.
Alexandria, La	421	282	200	23	177	36	9	20
De Soto, Mo	712	644	921	191	730	41	6	6
Ferriday, La	130	91	....	....	....	....	....	....
Gurdon, Ark	219	89	416	48	368	183	83	50
Helena, Ark	168	126	179	36	143	57	34	40
Hoxie, Ark	291	163	994	222	772	92	32	12
Lake Charles, La	105	73	83	8	75	7	7	9
Lexa, Ark	155	96	431	41	390	105	68	27
Little Rock, Ark	461	145	3,282	349	2,933	516	112	18
McGehee, Ark	643	392	901	75	826	144	22	17
Monroe, La	604	457	640	72	568	72	12	13
North Little Rock, Ark	2,419	2,413	9,714	1,232	8,482	1,293	53	15
Paragould, Ark	321	231	792	172	620	30	9	5
Poplar Bluff, Mo	188	90	404	20	384	129	69	34
Texarkana, Ark	216	191	633	85	548	111	51	20
Wynne, Ark	121	49	132	30	102	16	13	16
Total	7,174	5,552	19,722	2,604	17,118	2,832	....	17

Other towns such as McGehee, Monroe, Alexandria, and Helena, which carried on control work in the past, may not continue this year; these should be offered assistance and encouraged to keep the work going. The railroad should make every effort to inaugurate work in the remaining towns, which have never undertaken malaria control; or, at least, to adopt control measures in the shop areas. In connection with this survey malaria surveys were made of Little Rock, North Little Rock, McGehee, Monroe, Paragould, Wynne, and Pine Bluff.

ANTIMOSQUITO CAMPAIGNS IN AGRICULTURAL COMMUNITIES AND INDUSTRIAL TOWNS.

All of the towns listed above as shop and division points are important to the railroad from a revenue standpoint also. These and other commercial and industrial communities should be encouraged and assisted in inaugurating malaria control campaigns. The railroad will find assistance rendered such towns in the way of making surveys, supplying technical supervision, furnishing oil at cost, and drainage on company property, a profitable investment. The stamping out of malaria spells greater prosperity for these towns and increased revenue for the railroad. Many towns have already undertaken control work (Table 3) with gratifying results. Others, including the lumber mill towns of Glenmora, Clarks, Wilmar, Warren, and Arkansas City, with a combined capacity of 300,000,000 feet of lumber a year, recognize their handicap and are asking for malaria surveys and advice on control methods. The railroad is offered an unusual opportunity for leadership in the development of its territory which it can not afford to neglect. It can set an example of proper sanitation to its communities that will awaken their pride, encourage imitation, and convert the attitude of criticism against railroads to one of cooperation.

Malaria is essentially a rural disease and agriculture feels its influence. Agricultural products contribute largely to freight revenues; therefore the railroad would do wisely to cooperate with State and county health departments in promoting rural malaria control and to encourage the formation of drainage districts for health as well as agricultural benefits. Plantation owners and negro farmers might be permitted to cultivate the unused strips along the right of way in return for maintaining proper drainage along the company's lines, under the supervision of the section foremen. Such a plan would have little direct influence on the rural malaria rate, but it would foster imitation among farmers and would result in the extension of antimalaria drainage.

EDUCATIONAL MEASURES.

Employees and communities must be informed of the toll exacted by malaria and educated to the necessity for adequate control if the railroad's antimalaria program is to be a complete success. The railroad must "sell" malaria control to its own personnel as well as to the general public to obtain the cooperation that is so essential. Mill superintendents, city and county officials, business men's clubs, and others who control the purse strings of the community will finance their control work if properly approached. The right kind of educational propaganda is the seed from which will develop a permanent and luxuriant growth of malaria control work, with a minimum of expense to the company.

Exhibits showing in concrete form, by models, posters, and charts, the habits of mosquitoes, how they transmit malaria, proper methods of prevention, are valuable because easily understood by even the illiterate negro laborer. Their usefulness is multiplied if they are transported from place to place, to be shown to employees, city officials, the public, at county fairs and before school children. Educational measures should also include personal talks, with and without the exhibits; posters placed in waiting rooms, shops, and bunk cars; malaria primers distributed to floating gangs, to school children, and others;[5] public talks before business men's clubs and similar civic bodies.

ORGANIZATION AND COST.

The complete program outlined above can not be undertaken at once, but may be developed in the course of two or three years. An organization for handling it, when fully developed, and the estimated annual cost, would include:

(*a*)	1 directing sanitary engineer	$5,000
(*b*)	1 clerk-stenographer	1,200
(*c*)	3 sanitary inspectors, at $1,500	4,500
(*d*)	1 extra gang, part time, or equivalent local labor, for drainage and oiling	4,000
(*e*)	Exhibits, posters, printing, incidentals	500
(*f*)	Prophylactic quinine for floating gangs and section men	3,000
(*g*)	Travel expenses, director and inspectors	3,000
	Total	21,200

As a laboratory technician is essential for detecting the presence of malaria infection in the blood, the laboratory personnel employed in the employees' hospitals should be made available for this purpose in connection with the proposed program.

During the first year a reasonably practicable program would embrace: (1) improved screening of section houses and bunk cars; (2) cooperation with all towns already doing control work; (3) inauguration of antimosquito campaigns around two or three other shop areas, like Hoxie, Lexa, Poplar Bluff, preferably with municipal cooperation; (4) surveys and inauguration of work in two or three important mill towns; (5) educational measures leading to quinine prophylaxis the second year; (6) sterilization of winter carriers of the malarial organism among employees by hospital and contract surgeons. The first year's program will require the following:

(*a*)	1 directing sanitary engineer	$5,000
(*b*)	1 clerk-stenographer	1,200
(*c*)	1 sanitary inspector	1,500
(*d*)	1 extra gang, part time, or equivalent local labor, for drainage and oiling (approximate)	2,000
(*e*)	Exhibits, posters, printing, incidentals	500
(*f*)	Travel expenses, director and inspector	1,500
	Total	11,700

The success of the program will rest almost entirely on the proper selection of a director. The nature of the work will require a high-class sanitary engineer of broad experience in antimalaria work and a knowledge of general sanitation. He must be a man who can obtain the support of railroad officials, the confidence of railroad employees, and the cooperation of towns and mills. A high-class director will bring results far in excess of his higher salary by his ability to handle the work with greater efficiency, by his judgment of what is essential and what is wasteful expenditure, by his knowledge of State and Government health officers and their methods, and by his ability to get a maximum amount of work done by towns and mills with a minimum expense to the railroad.

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[5] The United States Public Health Service has published an excellent primer for this purpose entitled, "Malaria: Lessons on Its Cause and Prevention," Supplement No. 18 to the Public Health Reports.

While malaria constitutes the most serious sanitary problem on the southern divisions of the system, there are other health problems which the railroad may wish to solve in the near future, such as toilet and privy sanitation and a wholesome drinking water supply at stations and on trains. State and Federal legislation for protecting the health of employees and the traveling public on common carriers grows more stringent and far reaching every year, and the railroad will profit by being properly prepared to comply with practical regulations. The railroad malaria organization can and should be developed into a sanitary operating unit, with practically no additional expense. Malaria control is a warm-weather activity, and while surveys and educational work can be conducted in the winter months, the personnel can devote a portion of its time to other sanitary problems during the winter season. The sanitary unit should operate under the Chief Engineer or the Board of Hospital Managers, depending on whether the railroad or the Employees' Hospital Association finances it.

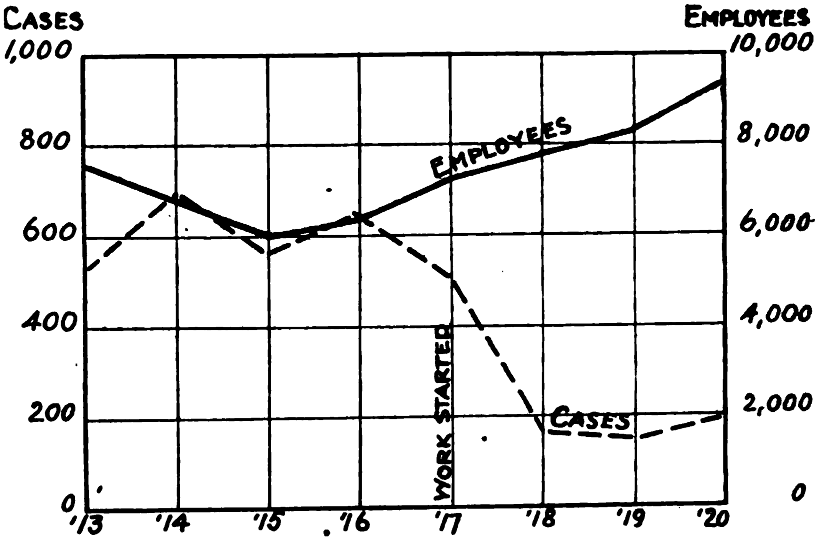

FIG. 22.—Chart showing reduction in hospital malaria cases among Cotton Belt (St. Louis Southwestern) Railway employees following antimalaria work.

MALARIA CONTROL EXPERIENCE OF OTHER RAILROADS.

The experience of other railroads that have undertaken the control of malaria demonstrates not only that such work is thoroughly practicable, but that it may be an excellent investment from a business viewpoint.

The St. Louis Southwestern Railway, operating in territory very similar to that of the southern divisions of the Missouri Pacific, has conducted malaria control since 1917 (fig. 22). Instigated and supported at first privately by Mr. Edwin Gould, chairman of the board of directors, the work proved so profitable that the company in 1920 established malaria control as a permanent railroad enterprise. From 1917 to 1920 Mr. Gould contributed over $40,000 to the work. In the beginning practically all the funds for field work were from this source; while in 1920 practically 75 per cent of the cost was supplied by the cities.

In four years there resulted a saving of $140,000 in hospital cases alone, an estimated saving of three or four times this amount in increased efficiency of railroad labor, and an increase in freight revenues that could not be estimated. The work is directed by a sanitary engineer responsible to the president. The program was gradually developed to include antimosquito campaigns in shop and mill towns, screening and swatting in bunk cars, cabooses, and section houses, educational work with the aid of a well-equipped exhibit car, quinine prophylaxis for bridge, building, and section men, and the sterilization of winter carriers. In 1919 the malaria control organization was developed into a sanitary control unit with a program embracing (1) malaria operations; (2) protection and certification of water supplies; (3) sanitary control of camp cars and cattle pens; (4) inspection of food furnished by labor contractors and by restaurants at division and shop points; (5) beautification of stations and section houses; (6) sanitary control of railroad property to improve its physical life; (7) rat eradication campaigns to reduce freight damage claims and destruction of physical property; (8) health education among employees.

The Central of Georgia Railway, as a result of a survey made by the United States Public Health Service in 1919, adopted a malaria control program directed primarily at the protection of employees. The director, a sanitary engineer, reports to the chief surgeon. The work embraces (1) screening of section houses and bunk cars; (2) drainage and oiling at two important shop towns; (3) cooperation with towns engaged in malaria control; (4) intensive educational measures, including talks to employees, especially foremen, distribution of malaria primers to section and bridge gangs, publication of articles on malaria prevention in the Right-of-Way Magazine, the use of posters in waiting rooms, shops, etc.; in fact, malaria control is advertised as widely as the safety-first campaign. Shop supervisors have noticed a great improvement in the efficiency of their skilled labor. The company is pleased with the results (fig. 23), and the prospects are that the work will be expanded in the near future.

On the Illinois Central Railway a malaria survey was completed last year by the United States Public Health Service, and this railroad is now undertaking antimosquito measures at certain of its shop areas. This railroad also has a health officer who looks after railroad sanitation. Other railroads evince a growing interest by inquiries regarding malaria control. The time seems not far distant when most of the southern railroads will go over the top in the attack against the greatest economic handicap of the South.

ACKNOWLEDGMENTS.

The cooperation of the following individuals is acknowledged with appreciation: Mr. H. W. Van Hovenberg, sanitary engineer for the St. Louis Southwestern Railway Co., for supplying in-patient hospital

records of the Missouri Pacific Railroad Employees' Hospital Association for the years prior to 1918; Mr. H. N. Old, assistant sanitary engineer, United States Public Health Service, for submitting copies of screening specifications adopted by the Central of Georgia Railway; the State health officers of Arkansas and Louisiana for information regarding the status of malaria control operations in the towns of their respective States; Messrs. C. S. Swartout, W. H. Vance, A. A. Miller, L. A. David, Joe Davis, R. H. Halsted, A. R. Taylor, W. P. Hayes, Drs. P. F. Vasterling, W. F. Smith, J. Q. Graves, The Freedman, W. H. De Clark, and other members of the engineering

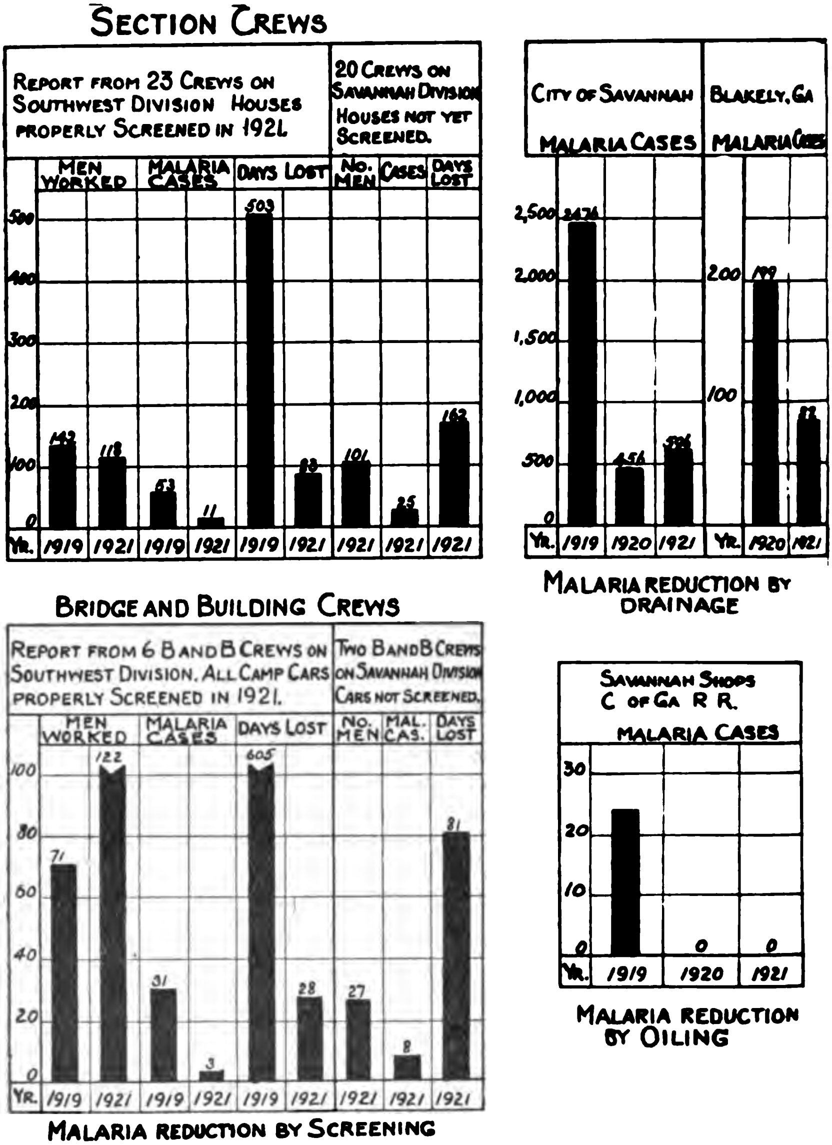

FIG. 23.—Chart showing results of malaria control on the Central of Georgia Railway.

operating, and medical staffs of the Missouri Pacific Railroad, for furnishing information requested or for accompanying the writer on the field survey; Surg. L. D. Fricks, Senior Sanitary Engineer J. A. LePrince, and Asst. Surg. K. F. Maxcy, United States Public Health Service, for reading and correcting the manuscript.

SUMMARY.

A malaria survey of the Missouri Pacific Railroad lines south of St. Louis was conducted during 1922 by the United States Public Health Service in cooperation with the Missouri Pacific Railroad Co. and the State health officers of Arkansas and Louisiana.

The purpose of the survey was to determine the prevalence of malaria among employees of the railroad, to ascertain the effect of malaria on operating costs and railroad revenues, and to make proper recommendations to the railroad for the economical control of this disease.

During the past 23 years the number of employees given hospital treatment for malaria averaged over 1,000 annually, which constituted 33 per cent of all hospital admissions and 45 per cent of all sick cases. For the same period injuries and surgical cases combined totaled only 75 per cent of malaria admissions. In 1921 over 50 per cent of all medical admissions to the Monroe Hospital were for malaria. In addition, over 4,000 employees receive out-patient treatment for malaria each year. The malaria census on four southern divisions shows that only 18 per cent of the malarial employees entered the hospital in 1921; that only 68 per cent even visited a doctor, and that 32 per cent of all employees interviewed gave positive histories for 1921. Employees receiving in-patient treatment for malaria spend an average of nine days in the hospital. The hospital malaria rate is eight times higher among employees working south of St. Louis than among those west of that point. The rate for the entire system (1920–21) was 11.5 per thousand, the maximum rate of 72.2 occurring on the Louisiana division. Of the various occupational groups on the southern divisions the bridge and building crews and the extra gangs have the highest hospital malaria rate (79.7) and shopmen the lowest (11.0). Coincident with the protection afforded to an increasing number of railroad employees by the inauguration of organized antimalaria work in communities along the Missouri Pacific Railroad, beginning in 1916, a marked drop occurred in the employees' hospital malaria rate.

With the subnormal personnel of 1920, the cost of hospital treatment for malarial employees that year was over $25,000. Transportation of malarial employees to and from the hospital and the pay of monthly employees absent from work with malaria are also tangible charges. Statements from railroad foremen indicate that malaria constitutes an enormous charge against the cost of operation by reducing the efficiency of labor, by producing a shortage of labor, and by creating a high labor turnover. Employees on malarious divisions are dissatisfied because of frequent sickness in the family and the excessive expenditures for medical attention.

A similar condition exists among the agricultural and industrial enterprises in this territory, and the railroad's passenger and freight traffic suffers the consequences. Letters from mill superintendents attest the true economy of controlling malaria and the increasing demand for control work.

Recommendations for a railroad malaria-control program embrace (1) protection of employees by methods most applicable to their mode of living, including effective screening of bunk cars and section houses, swatting of mosquitoes, prophylactic quinine for "floating" gangs and section men, antimosquito campaigns in shop towns and division points, and educational measures; (2) cooperation with State and local health departments in the inauguration of cooperative antimosquito campaigns in cities, mill towns, and farming communities on the line of the Missouri Pacific Railroad. For the first year a limited program is outlined at an estimated cost of $11,700; for succeeding years a fully developed program is estimated to cost $21,000. An experienced sanitary engineer is recommended as director, and the gradual development of the proposed malaria control organization into a sanitary operating unit is suggested. Similar work by other railroads is described.

APPENDIX I.

LETTERS FROM MILL SUPERINTENDENTS ON THEIR MALARIA PROBLEMS.

BRADLEY LUMBER CO., WARREN, ARK.

APRIL 25, 1922.

UNITED STATES PUBLIC HEALTH SERVICE,
Room 17, Courthouse, Memphis, Tenn.

DEAR SIRS: We are in receipt of yours of April 22 in which you advise that a survey is now being made of the territory through which the Missouri Pacific Railroad traverses, to determine the prevalence of malaria and its effect on industries located in the malarial district through which the Missouri Pacific traverses.

We are very much interested in learning how malaria may be eradicated from our district.

We have a great deal of sickness at certain seasons of the year among our men and their families; our doctors diagnose practically all the ailments from which our people suffer as malaria. We have made some feeble efforts in our living quarters by waging war on the mosquito to keep down malaria. However, we admit that we have not the knowledge to properly combat this malarial condition and will be very much pleased to have you investigate the malaria situation at our plant, and can assure you of our hearty cooperation in anything that you may recommend for the curtailment of this dreaded disease.

Yours very truly,

R. W. FULLERTON.

GATES LUMBER CO.

WILMAR, ARK., *April 29, 1922.*

UNITED STATES PUBLIC HEALTH SERVICE,
Room 17, Courthouse Building, Memphis, Tenn.

DEAR SIRS: Replying to yours of April 22 regarding the malaria survey to be made of the Missouri Pacific Railroad, our company physician reports as follows:

"In reply to Public Health Service letter of April 22, 1922, I will state the following:

"1. Mosquitoes are plentiful every mosquito season.

"2. Roughly, the percentage of malarial infection will average one patient, at least, to each family employed by the company. Many times the patient is the wage earner of the family.

"3. Personally, and as physician for the company, I think the malaria situation would justify the survey. I would be glad to see the survey made and to cooperate in every way possible.

"Respectfully,

"E. D. BUTLER, M. D."

We shall be glad to cooperate in any way possible in making this survey, and we feel quite sure that we can work up a great deal of interest through our town council in doing preventive work.

Yours very truly,

GATES LUMBER CO.,
B. A. CANNON,
Manager.

LOUISIANA CENTRAL LUMBER CO., CLARKS, LA.

MARCH 20, 1922.

UNITED STATES PUBLIC HEALTH SERVICE,
Room 17, Courthouse, Memphis, Tenn.

DEAR SIRS: We have your letter of the 15th instant referring to the health conditions in this community.

We are anxious to do everything we possibly can toward maintaining a healthy community, and are at this time spending about $1,500 to $2,000 in ditching around our town so as to drain all stagnant pools to prevent the breeding of mosquitoes.

If you should have a health officer in this community at any time in the near future we would be glad indeed to have him call on our local health officer, Dr. E. D. Gardner, and make any further suggestions that might occur to him toward improving conditions, as we realize that a community kept up in a sanitary condition means a great deal to the health of the people.

Yours very truly,

LOUISIANA CENTRAL LUMBER CO.,
A. W. JOHNSON,
Assistant to General Manager.

THE BREECE MANUFACTURING CO., ARKANSAS CITY, ARK.

APRIL 24, 1922.

UNITED STATES PUBLIC HEALTH SERVICE,
Room 17, Courthouse, Memphis, Tenn.

DEAR SIRS: Replying to your favor of April 22, we would be very glad to have you investigate malarial conditions at our plant. So far as the writer knows this has never been done, but we do know that a large percentage of our employees suffer from a certain amount of malaria during the summer and fall.

It has never been necessary for us to close our operation because of this but a great many of the employees, while not sick enough to leave work altogether, are in such physical condition that they are not able to put 100 per cent efficiency into their work. Of course this condition is not as bad now as it used to be several years ago but is still quite a menace to this country.

If there is anything we can do to assist you in this matter we shall be very glad to have you call on us.

Yours very truly,

THE BREECE MANUFACTURING CO.,
CARL L. WHITE, *Manager.*

APPENDIX II.

DEFECTS FOUND IN SCREENING OF MISSOURI PACIFIC PROPERTY.

A. *General.*
  1. Openings, cracks, knot holes in building or car requiring repair.
  2. Mesh less than 16 to the inch.
  3. Screen material worn, broken, or rusted: needs replacement; on doors kick strips are necessary.
  4. Patches on screen not securely laced on.
  5. Screens on hand, but not used.
  6. Screen loose from frame: needs molding over tacks.

B. *Doors.*
  1. Not all outside doors screened.
  2. Poor fit: too large; too small.
  3. Batten strips: None; not all around; not wide enough; edges facing screen door not in same vertical plane.
  4. Sill: None, or worn; needs bottom batten strip.
  5. Frame warped: should be made of heavier material and seasoned lumber.
  6. Frame sagged: needs diagonal bracing.
  7. Coil springs: None; stretched; too light.
  8. Hinges: Too small; insecurely attached; should be screwed, not nailed.
  9. Sliding doors on bunk cars left open: use hinged doors.
  10. Doors propped open: foreman should not permit.

on side doors it shall be low enough to be reached from the ground. A handle shall be fixed on the outside of all doors near the button.

14. Strips of wood at least three-fourths inch thick shall be nailed around the doorway on *all four sides* in such a manner that the door when closed will fit snugly against them. The screen-door frame shall be made one-fourth inch smaller all around than the opening to allow for swelling, and will thus have at least one-half inch contact all around against the strips. Door sills may be chiseled out to meet this requirement, otherwise the bottom strip shall be beveled to allow dirt to be swept out.

15. Screen doors now in use must be made to comply with these specifications.

Warning.—The malaria mosquito can get through a hole or crack as small as one-fourteenth of an inch, and may discover even a single such opening. Therefore a screened car should have no unscreened or uncaulked opening to invite mosquitoes.

APPENDIX V.

STANDARD QUININE TREATMENT FOR MALARIA ADOPTED BY THE NATIONAL MALARIA COMMITTEE AND APPROVED BY THE UNITED STATES PUBLIC HEALTH SERVICE.

Treasury Department,
Bureau of the Public Health Service,
Washington, March 31, 1922.

Bureau Circular No. 344.
To: Medical officers of the United States Public Health Service, and others concerned:
Subject: Treatment of malaria carriers in service hospitals.

Recent investigations in the treatment of malaria fevers have developed or emphasized the following facts:

1. Quinine remains the most effective drug known for the treatment and cure of malaria fevers.
2. The dosage generally employed in the United States is too small and the period of treatment too short to effect permanent cures except in a small percentage of cases.
3. The inadequately treated uncured malaria cases are of the greatest menace to the public health in that the majority of malaria-carrying mosquitoes are infected from them.
4. The treatment of malaria by the intravenous injection of quinine has a proper but limited field of usefulness; it has no curative advantage whatever over the oral administration of quinine in ordinary cases and should not be used as a routine treatment of malaria.

Your attention is directed to the Standard Quinine Treatment for Malaria as adopted by the National Malaria Committee and approved by the United States Public Health Service (Reprint 672). It is as follows:

"For the acute attack 10 grains of quinine sulphate by mouth three times a day for a period of at least three or four days, to be followed by 10 grains every night before retiring for a period of eight weeks. For infected persons not having acute symptoms at the time only the eight weeks' treatment is required."

This dosage should serve as the standard of treatment for ordinary malaria infection among all service beneficiaries.

No case of malaria should be discharged from a service hospital as "cured" immediately upon the subsidence of acute symptoms, but where patients no longer require, or where they refuse further hospital care, they should be furnished out-patient treatment and encouraged to take sufficient quinine to complete the period of treatment or effect a cure. Arsenic is frequently necessary in relieving these cases.

Blood examinations of all malaria cases undergoing treatment should be made at frequent intervals in order to determine progress of cure and whether patient is a carrier of malaria infection and hence dangerous to the public health.

H. S. Cumming,
Surgeon General.

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